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Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-46

September 1992

National Aeronautics and
Space Administration

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-46

July 31, 1992

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TABLE OF CONTENTS

FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included in this document to provide an integrated assessment of STS-47.

Shuttle Mission STS-46 was launched at 9:56 a.m. local 7/31/92

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 July 1992. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-104 Atlantis (12th flight), ET-48 (LWT 41), and BI052 SRB's. There were no vehicle or facility anomalies.

The vehicle was cryoloaded for flight on 31 July 1992. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice conditions outside of the established data base. The External Tank exhibited light condensate on the TPS acreage. The LH2 ET/ORB umbilical leak sensor detected no significant hydrogen during the cryoload. Droplets with vapor trails first appeared at T-4 hours 35 minutes and fell intermittently until T-3 hours. The cryogenic droplets may have been liquid air originating from the area of the 17-inch flapper valve torque tool access port TPS plug closeout. No unusual vapors or additional droplets were visible from stable replenish through launch. Two cracks were present in the forward surface of the -Y ET/SRB vertical strut cable tray near the longeron closeout interface. There was no offset and no ice/frost in the cracks. The cracks occurred in an area where the stress relief cut had been eliminated by design at the factory. Based on a debris (loss of material) and aerothermal analysis, the condition was accepted for flight.

A debris inspection of Pad 39B was performed after launch. No flight hardware was found. EPON shim material on the south holddown posts was intact, but debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 130 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. The hydrogen burn Ignitor at the southeast corner of the LH2 TSM malfunctioned with a faster activation and a more concentrated stream of sparks than the other five ignitors. The ignitor burned 1.3 seconds (nominal burn time is 8 to 12 seconds) and was completely expended by SSME ignition (E-3, 19, 20). Post launch analysis of the ignitor revealed a debond of the propellant from the inhibitor as the most likely cause of the malfunction. A stud hang-up occurred on HDP #7 (E-11). The stud remained fully extended as the aft skirt ascended. The stud pulled off three pieces of the EPON shim before dropping into the holddown post. No ordnance debris fell from any of the HDP DCS/stud holes. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The RH frustum had 10 MSA-2 debonds over fasteners and one area of missing TPS, which measured 2.5"x1.5", near the 381 ring frame between the +Y and +Z axes. The LH frustum was missing no TPS but had 12 MSA-2 debonds over fasteners. All Debris Containment System (DCS) plungers were seated properly. A 3-inch diameter piece of the HDP #3 EPON shim was missing prior to water impact (sooted/charred substrate). The HDP #7 stud hole was broached due to a stud hang-up at lift off as observed in the launch films. Small pieces of the EPON shim material adjacent to the stud hole had been pulled off by the stud.

A detailed post landing inspection of OV-104 (Atlantis) was conducted on 8 August 1992. The Orbiter TPS sustained a total of 236 hits, of which 22 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 186 hits, of which 11 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of Orbiter TPS debris hits was greater than average and the number of hits one inch or larger was average. No flight hardware was found during the post landing runway inspection or under the ET/ORB LH2 and LO2 umbilicals. All ORB/ET separation devices operated properly.

A variety of residuals were present in the Orbiter window samples and indicated sources such as Orbiter TPS, SRB BSM exhaust residue, natural landing site products, organics, and paint. These data do not indicate a single source of damaging debris as all of the other materials have been previously documented in post-landing samples. The residual sample data also gave no indication of debris trends when compared to previous missions.

A total of three Post Launch Anomalies were observed during this mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 30 July 1992 at 0830 hours with the following key personnel present:

S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
B. Speece	NASA - KSC	Lead, ET Thermal Protection
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
J. Rivera	NASA - KSC	Lead, ET Structures
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Mech Sys
J. Blue	LSOC - SPC	ET Processing
J. Kercsmar	LSOC - SPC	ET Processing
M. Wollam	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
Z. Byrns	NASA - JSC	Level II Integration
M. McBain	MMC - MAF	ET TPS Testing/Certif
J. Stone	RI - DNY	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Vehicle Integration
J. Cook	MTI - LSS	SRM Processing
R. Kretz	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 July 1992 from 0930 - 1035 hours. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-104 Atlantis (12th flight), ET-48 (LWT 41), and BI052 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

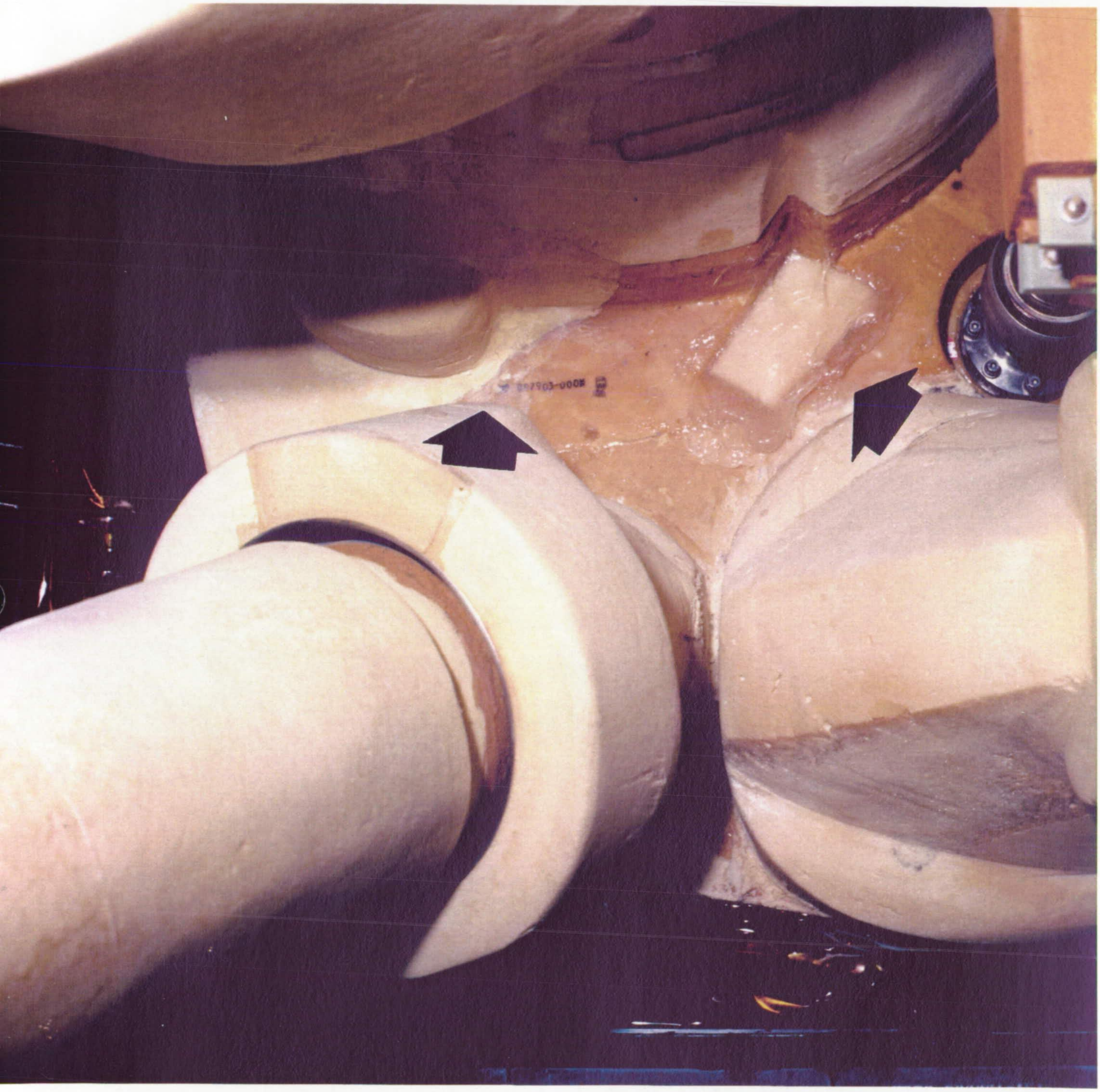
Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload and launch, tygon tubes for hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

There were no significant vehicle anomalies.

Three MLP deck access plate bolts were loose. Small pieces of debris, such as tie-wraps, TPS trimmings, deck scale, and rust flakes, were scattered around the MLP deck.

These discrepancies were corrected real-time by Pad Operations and no items were entered in S0007, Appendix K.

LH (-Y) vertical strut/cable tray TPS covering prior to cryogenic fuel loading. Cracks have appeared in this general area after cryoload due to the elimination of a stress relief gap as part of a manufacturing process enhancement change.



LH2 ET/ORB umbilical, including aft pyrotechnic canister closeout and 17-inch flapper valve actuator access port foam plug closeout, prior to cryogenic fuel loading.

3.0 LAUNCH

STS-46 was launched at 31:13:56:48 GMT (09:56:48 a.m. local) on 31 July 1992.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 31 July 1992 from 0455 to 0635 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	74.8 F
Relative Humidity:	93.8 %
Wind Speed:	5.7 Knots
Wind Direction:	215 Degrees

The portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

3.2 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers and water spray boiler plugs were intact. Less than usual ice/frost was present at the SSME heat shield-to-nozzle interfaces. Condensate was present on all SSME heat shields and on base heat shield tiles. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 SOLID ROCKET BOOSTERS

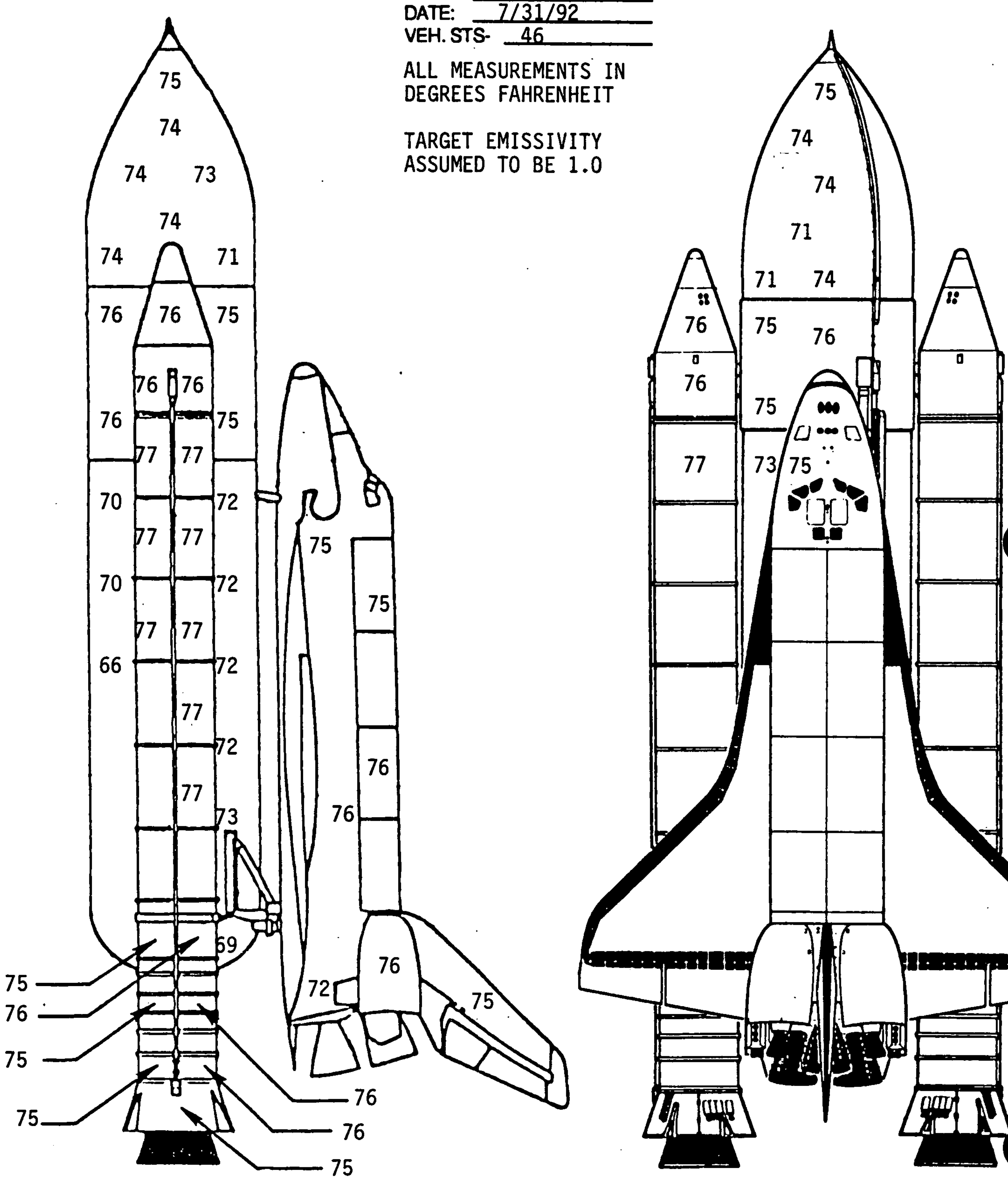
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 75 and 78 degrees F. In comparison, temperatures measured by the hand-held Cyclops radiometer ranged from 74 to 78 degrees F and the GEI (Ground Environment Instrumentation) measured temperatures ranging from 77 to 82 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 81 degrees F, which was within the required range of 44-86 degrees F.

SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0500 - 0630 EDT
DATE: 7/31/92
VEH. STS- 46

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



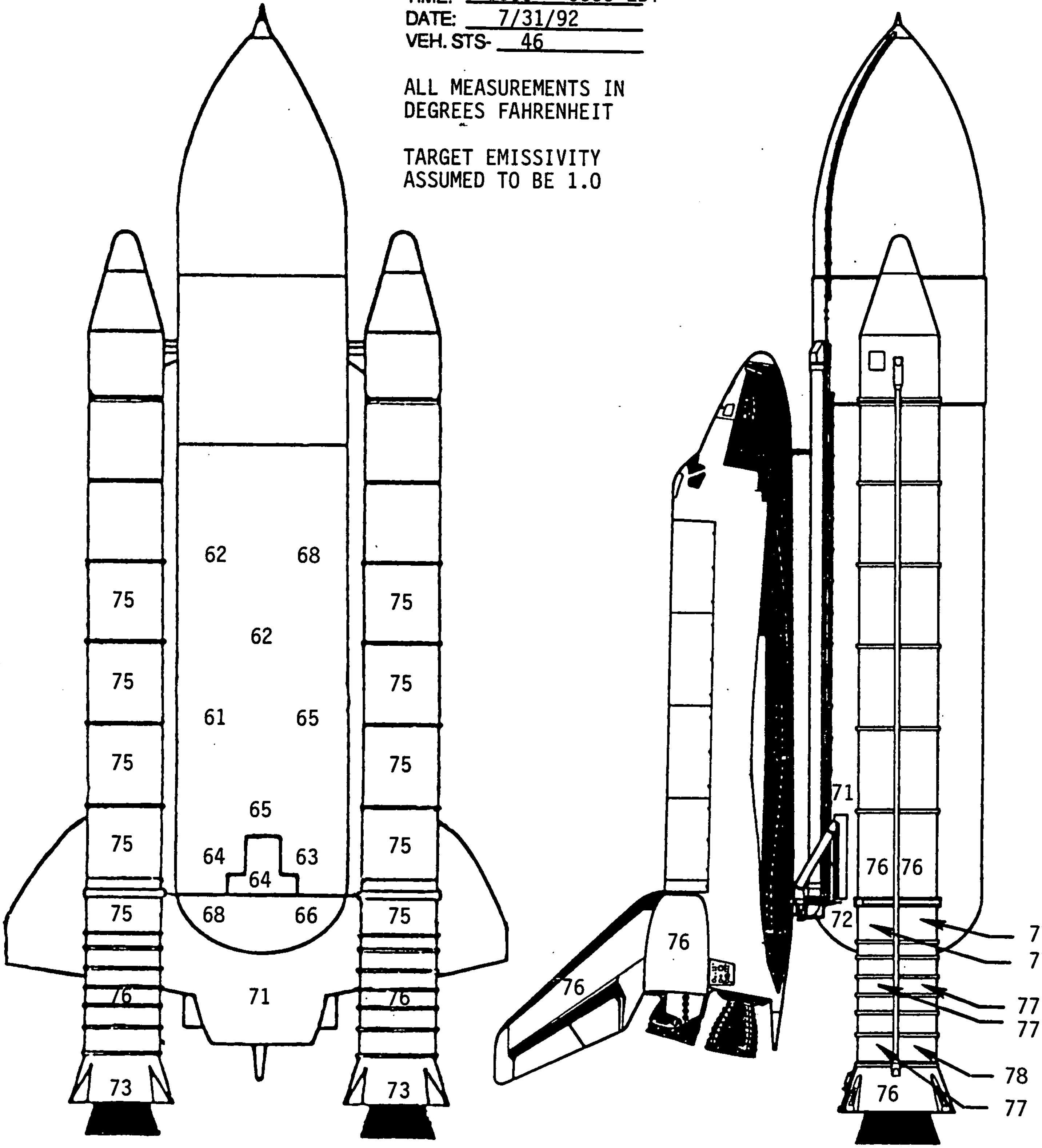
EGG/V-3

SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0500 - 0630 EDT
DATE: 7/31/92
VEH. STS- 46

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



EGG/V-343C

3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0200 to 0945 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

There was no ice/frost accumulation and light condensate on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The STI measured surface temperatures that averaged 75 degrees F on the ogive and 73 degrees Fahrenheit on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 73 degrees F on the ogive and 69 degrees F on the barrel; SURFICE predicted temperatures of 66 degrees F on the ogive and 61 degrees F on the barrel.

Some light run-off condensate was present on the intertank TPS. No frost spots appeared in the stringer valleys at either the LH2 and LO2 tank-to-intertank flanges. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The portable STI measured surface temperatures that averaged 75 degrees F and the Cyclops radiometer measured temperatures that averaged 74 degrees F.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 68 degrees F on the upper LH2 tank and 67 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 67 degrees F on the upper LH2 tank and 68 degrees F on the lower LH2 tank; SURFICE predicted temperatures of 54 degrees F on the upper LH2 tank and 67 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry. Two cracks (8 and 4 inches, respectively, and 1/4-inch wide) were present in the forward surface TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. Both cracks exhibited no offset and were not filled with ice or frost. Due to the proximity of the cracks, the possibility existed for loss of BX-250 TPS in flight. Thermal and flow field analyses showed no aerothermal or debris concerns.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

STS- 46	TEST S0007 LAUNCH	DATE: 31 July 1992	T-0 TIME: 09:56:48 DATE: 7/31/92	NASA KSC Ice/Frost/Debris Team
ORBITER 104	ET 48	SRB BI-052	MLP 1	PAD B

LO2		LH2	
CHILLDOWN TIME: 01:34	FAST FILL TIME: 03:03	CHILLDOWN TIME: 01:23	FAST FILL TIME: 02:24
SLOW FILL TIME: 02:00	REPLENISH TIME: 04:15	SLOW FILL TIME: 01:35	REPLENISH TIME: 04:37

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
200	76.00	88.8	72.62	5	221	II	2.95	65.40	0.0028	-0.1451	II	2.95	59.55	0.0045	-0.1148	II	1.60	52.24	0.0040	-0.0804	II	6.80	65.48	0.0056	-0.2518
215	76.00	88.6	72.55	7	228	II	4.13	67.06	0.0029	-0.1905	II	4.13	62.50	0.0048	-0.1591	II	2.24	55.28	0.0044	-0.0812	II	9.52	67.39	0.0057	-0.3488
230	75.80	89.0	72.48	7	221	II	4.13	66.93	0.0030	-0.1895	II	4.13	62.36	0.0049	-0.1582	II	2.24	55.12	0.0044	-0.0806	II	9.52	67.27	0.0057	-0.3472
245	76.00	89.2	72.74	8	217	II	4.72	67.80	0.0030	-0.2140	II	4.72	63.70	0.0050	-0.1821	II	2.56	56.92	0.0047	-0.0943	II	10.88	68.19	0.0057	-0.3992
300	75.80	89.8	72.74	7	205	II	4.13	67.11	0.0030	-0.1909	II	4.13	62.55	0.0049	-0.1595	II	2.24	55.31	0.0045	-0.0813	II	9.52	67.46	0.0058	-0.3498
315	75.80	90.6	72.99	6	214	II	3.54	66.54	0.0030	-0.1693	II	3.54	61.42	0.0048	-0.1384	II	1.92	53.65	0.0043	-0.0809	II	8.16	66.81	0.0059	-0.3034
330	75.40	90.8	72.65	7	218	II	4.13	66.89	0.0031	-0.1893	II	4.13	62.31	0.0050	-0.1580	II	2.24	55.03	0.0045	-0.0802	II	9.52	67.26	0.0059	-0.3472
345	75.40	91.0	72.71	8	212	II	4.72	67.55	0.0031	-0.2120	II	4.72	63.42	0.0051	-0.1802	II	2.56	56.58	0.0047	-0.0929	II	10.88	67.97	0.0060	-0.3960
400	75.20	91.2	72.58	6	204	II	3.54	65.99	0.0031	-0.1659	II	3.54	60.84	0.0048	-0.1350	II	1.92	53.00	0.0043	-0.0779	II	8.16	66.28	0.0059	-0.2973
415	75.40	91.4	72.84	6	203	II	3.54	66.26	0.0031	-0.1676	II	3.54	61.13	0.0049	-0.1367	II	1.92	53.31	0.0043	-0.0793	II	8.16	66.55	0.0059	-0.3004
430	75.20	91.6	72.70	6	203	II	3.54	66.08	0.0031	-0.1664	II	3.54	60.93	0.0049	-0.1356	II	1.92	53.09	0.0043	-0.0783	II	8.16	66.38	0.0060	-0.2984
445	74.80	92.2	72.49	6	206	II	3.54	65.76	0.0031	-0.1644	II	3.54	60.59	0.0049	-0.1336	II	1.92	52.70	0.0043	-0.0764	II	8.16	66.07	0.0060	-0.2949
500	75.40	92.8	73.27	6	204	II	3.54	66.57	0.0032	-0.1696	II	3.54	61.45	0.0050	-0.1386	II	1.92	53.62	0.0044	-0.0806	II	8.16	66.88	0.0061	-0.3043
515	74.40	93.0	72.34	6	195	II	3.54	65.48	0.0031	-0.1627	II	3.54	60.29	0.0049	-0.1319	II	2.52	55.59	0.0047	-0.0878	II	2.28	54.42	0.0046	-0.0786
530	74.60	93.8	72.78	6	194	II	3.54	65.88	0.0032	-0.1652	II	3.54	60.71	0.0050	-0.1344	II	2.52	56.04	0.0048	-0.0897	II	2.28	54.87	0.0046	-0.0804
545	74.40	94.0	72.64	6	206	II	3.54	65.70	0.0032	-0.1641	II	3.54	60.52	0.0050	-0.1332	II	1.92	52.58	0.0043	-0.0757	II	8.16	66.04	0.0062	-0.2946
600	74.60	94.2	72.90	6	221	II	3.54	65.97	0.0032	-0.1658	II	3.54	60.81	0.0050	-0.1349	II	1.92	52.88	0.0044	-0.0771	II	8.16	66.31	0.0062	-0.2978
615	75.20	94.8	73.68	5	225	II	2.95	65.80	0.0032	-0.1475	II	2.95	59.96	0.0049	-0.1170	II	1.60	52.33	0.0043	-0.0812	II	6.80	65.99	0.0062	-0.2571
630	74.80	94.6	73.22	5	238	II	2.95	65.29	0.0031	-0.1447	II	2.95	59.42	0.0048	-0.1142	II	1.60	51.79	0.0042	-0.0786	II	6.80	65.48	0.0062	-0.2521
645	75.00	95.0	73.54	5	248	II	2.95	65.61	0.0032	-0.1465	II	2.95	59.76	0.0049	-0.1159	II	2.15	54.98	0.0046	-0.0802	II	6.05	65.00	0.0061	-0.2275
700	75.00	95.4	73.66	4	251	II	2.36	64.37	0.0030	-0.1231	II	2.36	57.55	0.0045	-0.0931	II	1.72	52.29	0.0043	-0.0805	II	4.84	63.36	0.0059	-0.1830
715	75.20	94.8	73.68	4	251	II	2.36	64.48	0.0030	-0.1236	II	2.36	57.67	0.0045	-0.0936	II	1.72	52.43	0.0043	-0.0812	II	4.84	63.46	0.0059	-0.1837
730	75.20	95.0	73.74	6	256	II	3.54	66.83	0.0033	-0.1713	II	3.54	61.72	0.0051	-0.1402	II	2.58	57.34	0.0050	-0.0967	II	7.26	66.46	0.0063	-0.2746
745	76.00	93.8	74.17	5	270	II	2.95	66.51	0.0032	-0.1515	II	2.95	60.72	0.0049	-0.1208	II	2.15	55.99	0.0047	-0.0851	II	6.05	65.88	0.0061	-0.2355
800	77.00	93.0	74.93	4	252	II	2.36	66.21	0.0030	-0.1320	II	2.36	59.53	0.0046	-0.1018	II	1.72	54.41	0.0043	-0.0905	II	4.84	65.18	0.0059	-0.1966
815	77.60	91.4	75.03	5	254	II	2.95	67.82	0.0031	-0.1590	II	2.95	62.13	0.0048	-0.1281	II	2.15	57.52	0.0047	-0.0927	II	6.05	67.15	0.0060	-0.2471
830	78.40	89.9	75.35	5	259	II	2.95	68.39	0.0030	-0.1624	II	2.95	62.75	0.0048	-0.1314	II	2.15	58.20	0.0046	-0.0961	II	6.05	67.70	0.0059	-0.2522
845	79.20	86.6	75.08	5	270	II	2.95	68.53	0.0028	-0.1631	II	2.95	62.92	0.0046	-0.1322	II	2.15	58.42	0.0045	-0.0977	II	6.05	67.79	0.0056	-0.2529
900	80.40	84.6	75.60	4	297	II	2.36	68.24	0.0026	-0.1421	II	2.36	61.76	0.0043	-0.1116	II	1.84	57.68	0.0042	-0.1031	II	4.92	67.19	0.0053	-0.2144
915	81.00	82.4	75.44	4	289	II	2.36	68.40	0.0025	-0.1428	II	2.36	61.94	0.0042	-0.1124	II	1.72	57.20	0.0041	-0.1044	II	4.84	67.19	0.0052	-0.2119
930	81.80	80.8	75.68	5	315	II	2.95	70.06	0.0025	-0.1721	II	2.95	64.56	0.0043	-0.1409	II	2.30	60.97	0.0044	-0.1076	II	6.15	69.32	0.0051	-0.2703
945	82.80	78.2	75.73	6	335	II	3.54	71.33	0.0023	-0.2011	II	3.54	66.57	0.0043	-0.1693	II	2.76	63.33	0.0045	-0.1294	II	7.38	70.79	0.0048	-0.3252
T-0	83.60	76.2	75.78	7	301	II	4.13	72.31	0.0021	-0.2296	II	4.13	68.10	0.0042	-0.1972	II	3.22	65.19	0.0045	-0.1518	II	8.61	71.88	0.0044	-0.3797
AVG	76.62	90.26	73.65	5.70	SSW-WNW		3.36	66.94				3.36	61.58				2.11	55.55				7.09	66.10		

Period of Ice Team Inspection

Figure 3. "SURFICE" Computer Predictions

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Amounts of ice/frost on the top, aft, and inboard sides of the LH2 ET/ORB umbilical purge barrier were typical; and less than usual on the outboard side. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost had also formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. No ice or frost had formed on the cable tray vent hole. Ice/frost 8"x4" had formed at the forward corner of the 17-inch flapper valve actuator access port foam plug closeout. A strong flow of purge gas vented from this area. The ice/frost formation was acceptable for launch per the NSTS-08303 criteria. MPS evaluated the blowing purge gas leak and accepted the condition for flight.

Droplets with vapor trails first appeared at T-4 hours 35 minutes and dropped intermittently until T-3 hours. The cryogenic droplets may have been liquid air originating from the area of the TPS plug leak. No unusual vapors or additional droplets were visible from stable replenish through launch.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle. There was no flight hardware or TPS contact.

The summary of Ice/Frost Team observations/anomalies consisted of seven OTV recorded items:

Anomaly 001 documented droplets with vapor trails falling from the area of the LH2 ET/ORB umbilical and most likely was liquid air originating from the 17-inch flapper valve torque tool access port TPS plug closeout or nearby area. The foam plug exhibited a blowing purge gas leak with ice/frost formation at the forward corner. The ice/frost formation was acceptable per the NSTS-08303 criteria. MPS accepted the blowing purge gas condition as acceptable for launch.

Anomaly 002 and PR ET-48-TS-0027 documented two cracks (8 and 4 inches, respectively, and 1/4-inch wide) in the forward surface TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. Both cracks exhibited no offset and were not filled with ice or frost. Due to the proximity of

the cracks, the possibility existed for loss of BX-250 TPS in flight. Thermal and flow field analyses showed no aerothermal or debris concerns.

Anomaly 003 recorded a 2-inch diameter ice/frost formation at the -Y vertical strut to ET/SRB cable tray fairing aft side bondline. The condition was acceptable per NSTS-08303.

Anomaly 004 recorded a 1-inch diameter ice/frost formation at the +Y vertical strut to ET/SRB cable tray fairing aft side at the vent/drain hole. The condition was acceptable per NSTS-08303.

Anomaly 005 documented ice/frost and froth spots at the LH2 dome apex closeout bondline. The condition was acceptable for launch per the NSTS-08303 criteria.

Anomaly 006 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. These ice and frost formations were acceptable per NSTS-08303.

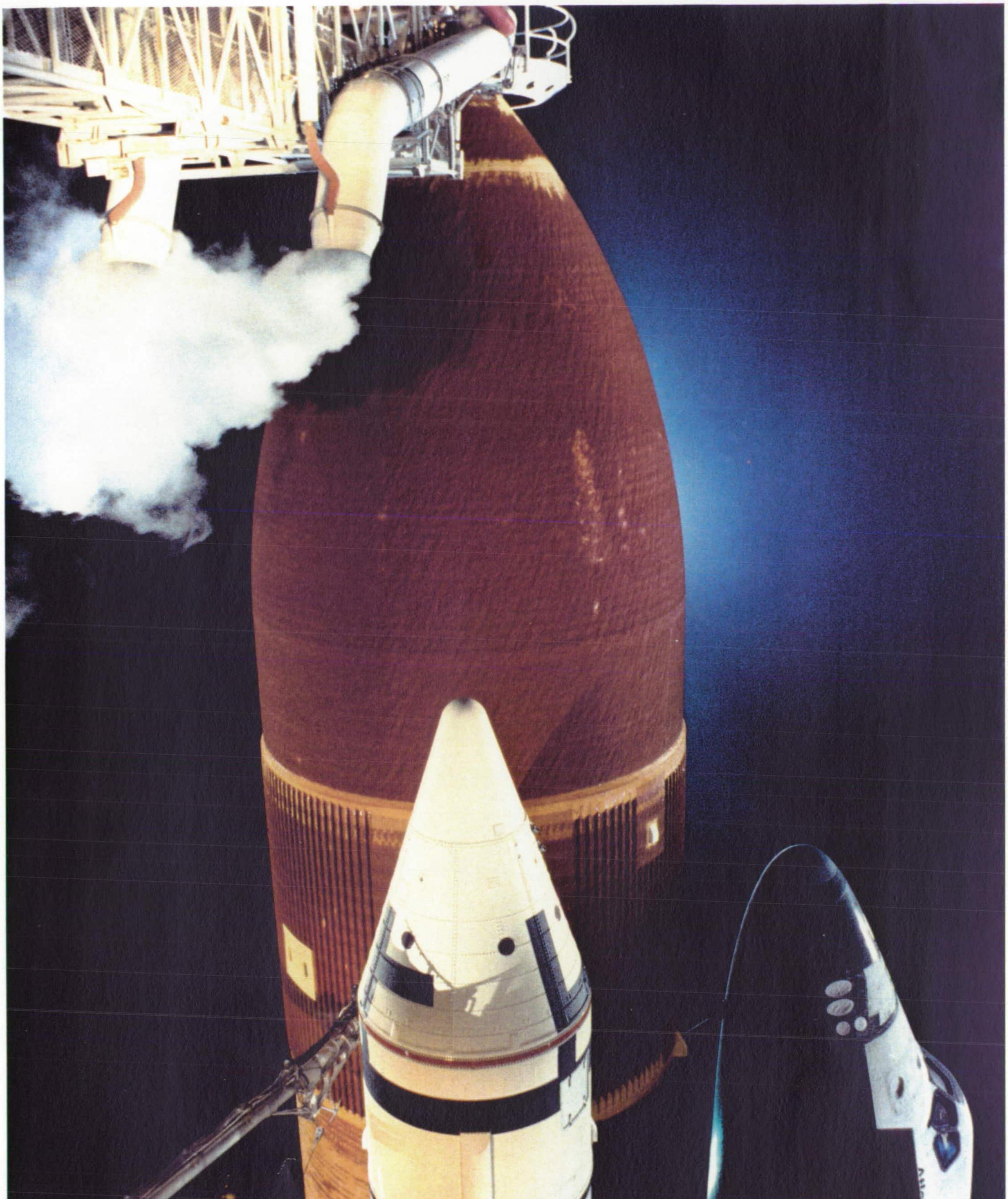
Anomaly 007 (documentation only) recorded ice/frost formations on the LO2 umbilical purge vents and LH2 umbilical purge vents, purge barrier (baggie), and LH2 recirculation line bellows. The ice/frost formations were acceptable per NSTS-08303.

3.5 FACILITY

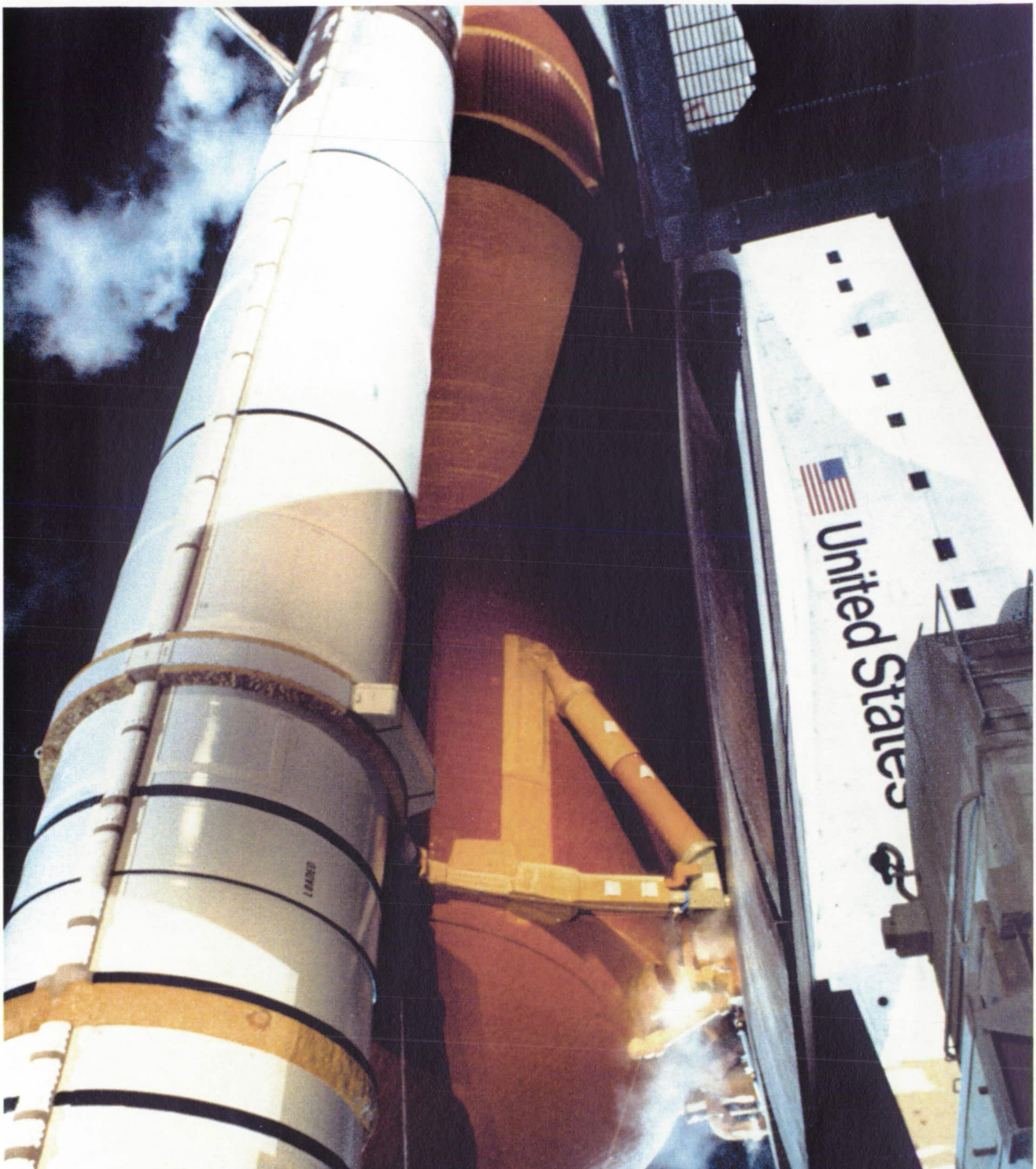
All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

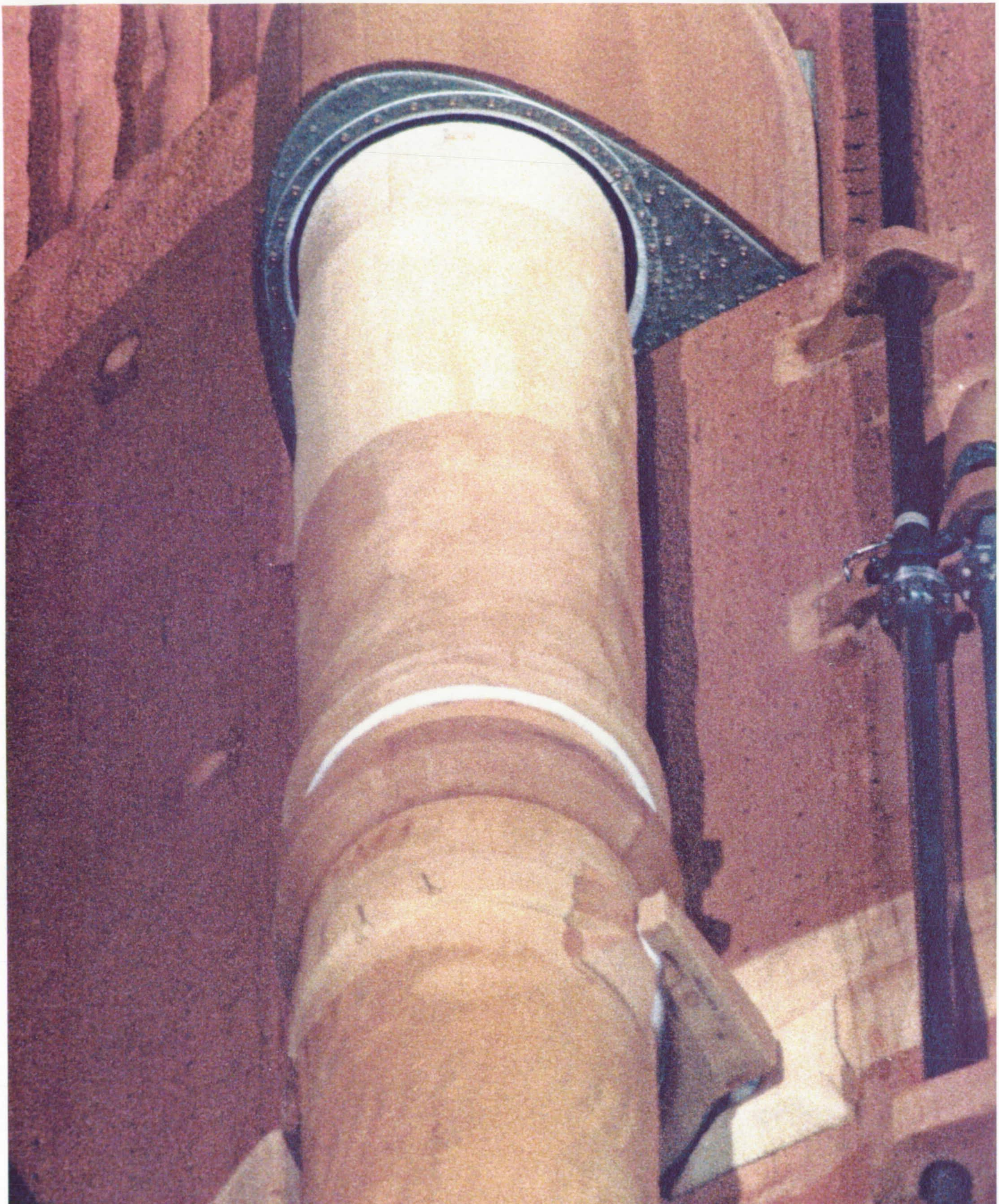
Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles had formed on the GOX vent ducts.



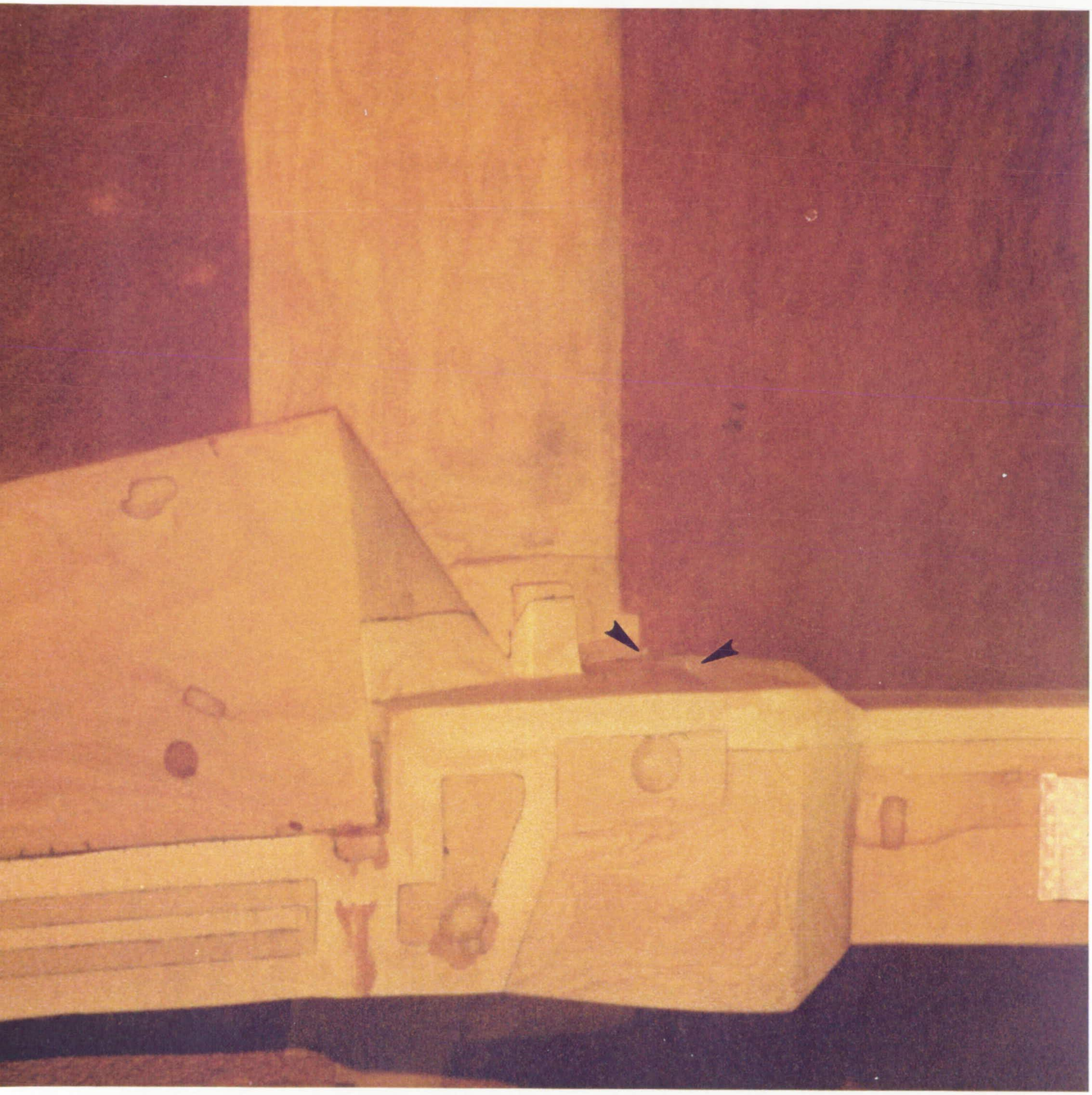
Light condensate, but no ice or frost accumulation, was present on the ET LO2 tank ogive and barrel section TPS acreage



Light condensate, but no ice or frost accumulation, was present on the LH2 tank and aft dome TPS acreage



Typical amounts of ice/frost had formed in the LO2 feedline support bracket and upper bellows



Two cracks, 8 and 4 inches long, respectively, appeared in the LH (-Y) vertical strut/cable tray forward facing TPS covering near the longeron closeout interface. A stress relief cut in the TPS to allow for structural movement had been deleted by design.

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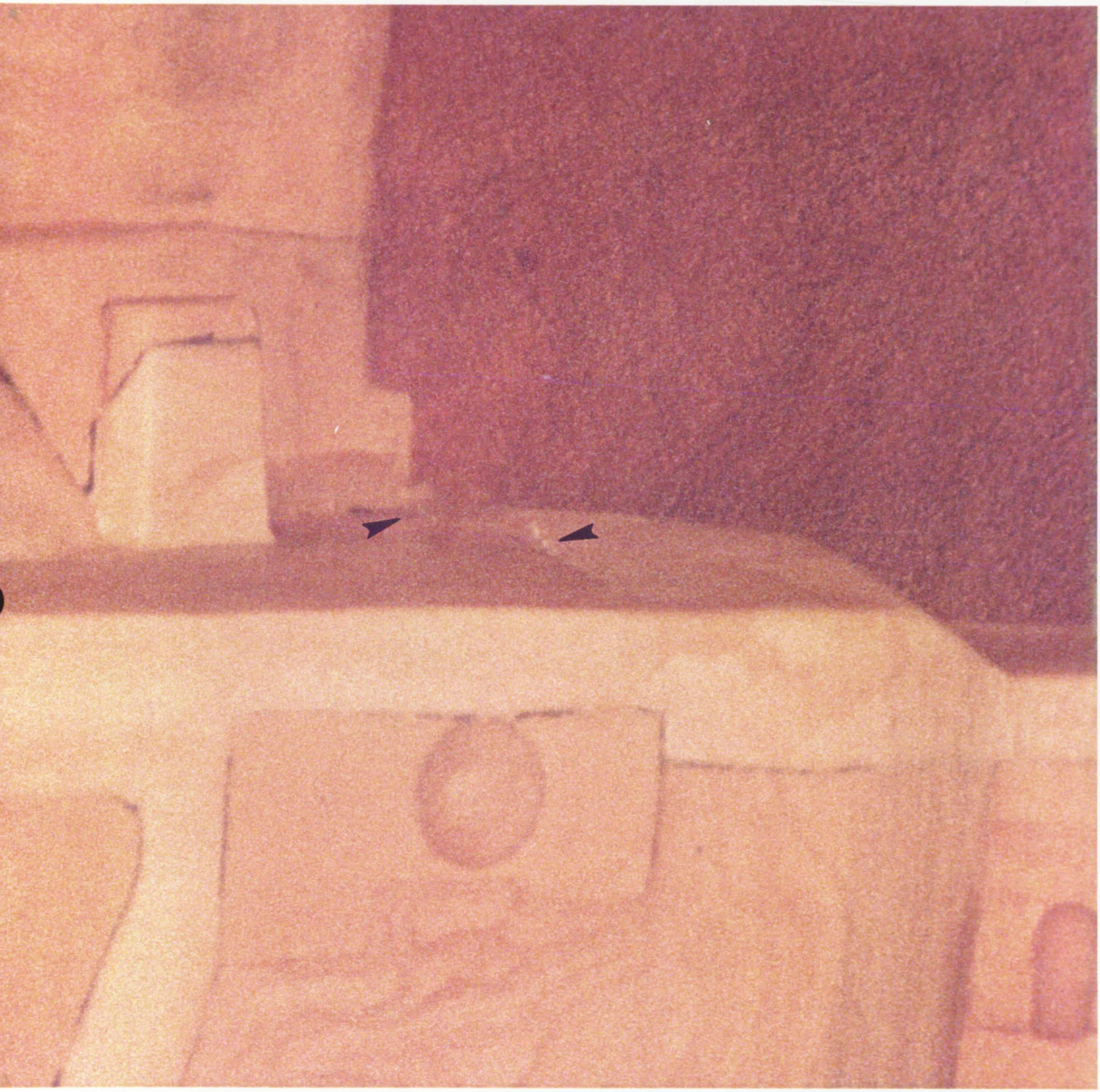
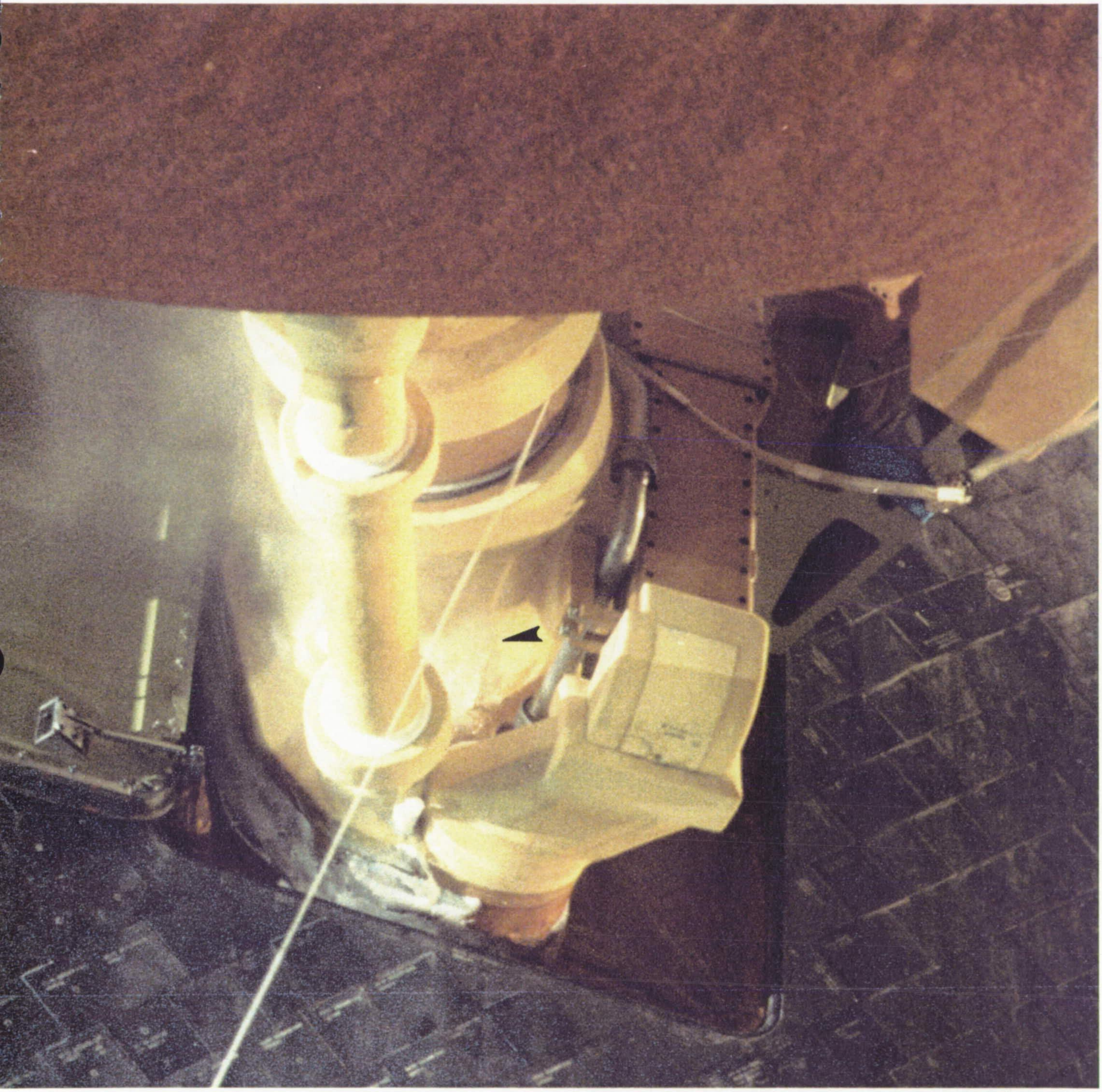


Both cracks exhibited no offset and were not filled with ice or frost. Due to the proximity of the cracks, the possibility existed for loss of BX-250 TPS in flight. Thermal and flow field analyses showed no aerothermal or debris concerns.



Ice/frost formations on the inboard side of the LH2 ET/ORB umbilical/purge barrier, the lower plate gap purge vent, and in the LH2 recirculation line bellows were typical. Ice/frost accumulated on the thin foam and bondline around the aft pyro canister. Ice, 8"x4" in size, had formed at the forward corner of the 17-inch flapper valve actuator access port foam plug closeout. A strong flow of purge gas vented from this area.

Less than usual ice/frost had formed on the outboard and top sides of the LH2 ET/ORB umbilical/purge barrier. Typical amounts of ice had accumulated on the upper plate gap and pyro canister purge vents, and in the LH2 recirculation line bellows

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and Pad apron was conducted on 31 July 1992 from Launch + 2 to 4 1/2 hours. No flight hardware or TPS materials were found.

EPON shim material was intact on all south holddown posts. However, the sidewall material was partially debonded on HDP #1 and #5. There was no visual indication of a stud hang-up on any of the south holddown posts. No ordnance fragments were found in the south HDP stud holes. All of the north HDP doghouse blast covers were in the closed position and exhibited less than normal erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilicals exhibited minor damage including deformation of the sacrificial connector savers.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. The GH2 vent line latched on the eighth tooth. There were no loose cables, but the north latch appeared to have contacted the north saddle stabilizer. The damage from this contact was minimal and has occurred on previous launches.

Damage to the facility included:

1. A broken light near the FSS 95 foot level elevator.
2. A missing cable tray cover on the RSS 135 foot level.
3. A door on an air regulator box on the FSS 155 foot level was open and bent.
4. Apparent impact damage to the back of a GN2/GHe Service Panel pressure gauge on the FSS 155 foot level.
5. An OIS box cover from the FSS 275 foot level was found on the FSS 255 foot level.

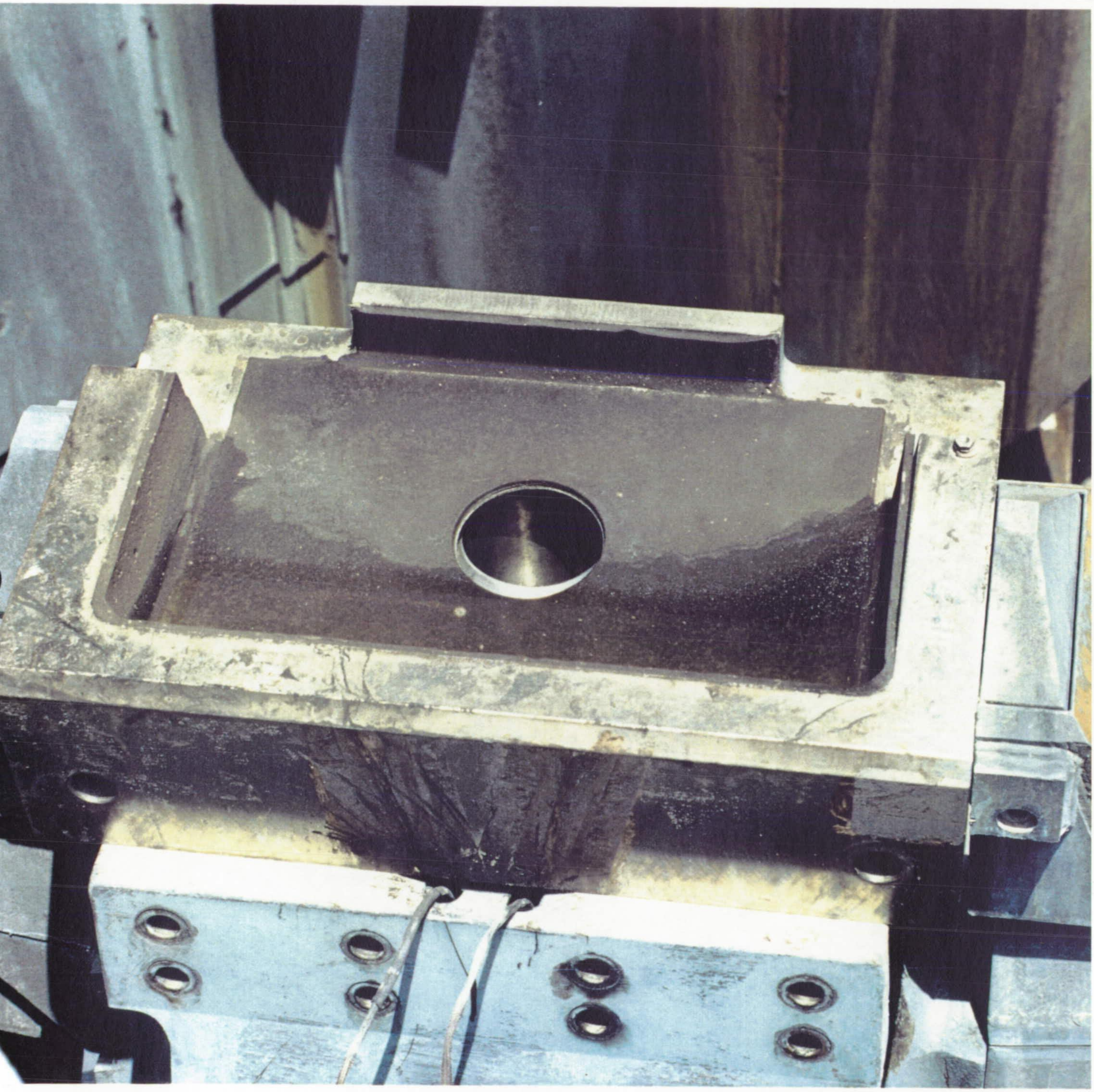
All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

An inspection of the pad acreage, the flame trench, the beach from UCS-9 to the Titan complex, the beach road, the railroad tracks, and the water areas around the pad and under the flight path revealed no flight hardware or additional pad damage.

MLP-1 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. All sensor readings were consistent with previous launches and within nominal limits.

Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 74 particles were imaged in the T+140 to 332 second time period. Thirty-seven of the particles were imaged by only one radar, 32 particles were imaged by two radars, and 5 particles were imaged by all three radars. Compared to STS-49, the number of detected particles was slightly larger but were within the same signal strength as most of the previous flights.

Post launch pad inspection anomalies are listed in Section 9.



Plume erosion of the south SRB holddown posts was typical. EPON shim material was intact, but debonded along the sidewalls.

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All of the north holddown post doghouse blast covers were in the closed position and showed less than usual erosion

5.0 FILM REVIEW AND PROBLEM REPORTS

Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 106 film and video data items, which included thirty-seven videos, forty-six 16mm films, nineteen 35mm films, and four 70mm films, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

The hydrogen burn ignitor at the southeast corner of the LH2 TSM malfunctioned with a faster activation and a more concentrated stream of sparks than the other five ignitors. The ignitor burned 1.3 seconds (nominal burn time is 8 to 12 seconds) and was completely expended by SSME ignition (E-3, 19, 20). Post launch analysis of the ignitor revealed a debond of the propellant from the inhibitor as the most likely cause of the malfunction. X-rays were taken of the remaining ignitors in this lot and examined for anomalies. In addition, a burst pressure test was performed on six expended ignitor casings. The welds on the ignitor end caps failed between 6500 to 7000 psig. Mathematical analysis determined the worst case internal pressure based on a burn time of 1.3 seconds and 100 percent burning of the propellant surface area would be 3900 psig. The analysis concluded the ignitor casing would not fail during an abnormal propellant burn.

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. Numerous flashes and streaks occurred in the SSME #1 and #2 Mach diamonds (OTV 170, 171, E-2, 3). Fore-aft movement of the base heat shield between the SSME cluster was visible during the early stages of SSME ignition (E-20, 76, 77). This phenomenon has occurred on previous launches.

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals. Some pieces were deflected by the umbilical cavity sill. No damage to Orbiter tiles or ET TPS was visible. Although some cryogenic drips with vapor trails were detected during tanking and stable replenish, there were no unusual vapors or cryogenic drips from the ET/ORB umbilicals during ignition and liftoff (OTV 109, 154, 163, 164).

SSME ignition vibration and acoustics caused the loss of tile surface coating material from the aft surface of the RH RCS stinger (E-17, 19).

Two dark objects passed by the vertical stabilizer moving left to right, but there was no apparent vehicle contact (OTV 170, 171). A dark particle fell aft through the field of view past the lower surface of the elevon. A second small particle moving in the same direction lightly contacted the body flap without causing tile damage (E-17, frame 3739).

A flat, thin, triangular object (possibly cardboard) with a major dimension of 6 inches fell downward (frame 1820) through the field of view near the LH wingtip/LH SRB area (E-36). A dark object, probably originating from the facility, crossed the FOV from left to right at frame 4779, but did not contact the vehicle (E-40). A second dark object, which appeared to be a bird, first appeared near the -Y thrust strut and fell aft without contacting the vehicle (E-40, frame 5060). A facility debris particle, black on one side and light on the other side, fell past the LH SRB prior to liftoff (E-7, 30). This may have been the object observed in film item E-36. A debris particle, originating from the exhaust hole, fell below the elevon without contacting the vehicle (E-31).

Light frost was present in the ET GOX vent louvers. There was no TPS damage to the ET nose cone acreage, footprint, or fairing (OTV 160, 161, 162). Vehicle "twang" as measured by the excursion of the ET pressure spike was approximately 32 inches (E-79).

A stud hang-up occurred on HDP #7 (E-11). The stud remained fully extended as the aft skirt ascended. The stud pulled off three pieces of the EPON shim before dropping into the holddown post.

No ordnance debris fell from any of the HDP DCS/stud holes.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 163). GUCP disconnect from the External Tank was nominal (OTV 104). The GH2 vent arm retracted and latched properly with no rebound. There was no excessive slack in the static retract lanyard (E-33, 41, 42, 48, 50).

A light colored, soft focused object first appeared (at the top of the frame) against the LH SRB case and fell aft along the -Z side of the External Tank at 56:59.012 GMT in film item E-57. Review of film item E-59, which covers the forward part of the vehicle, did not show the object during this same time frame. The origin of the object has not yet been determined.

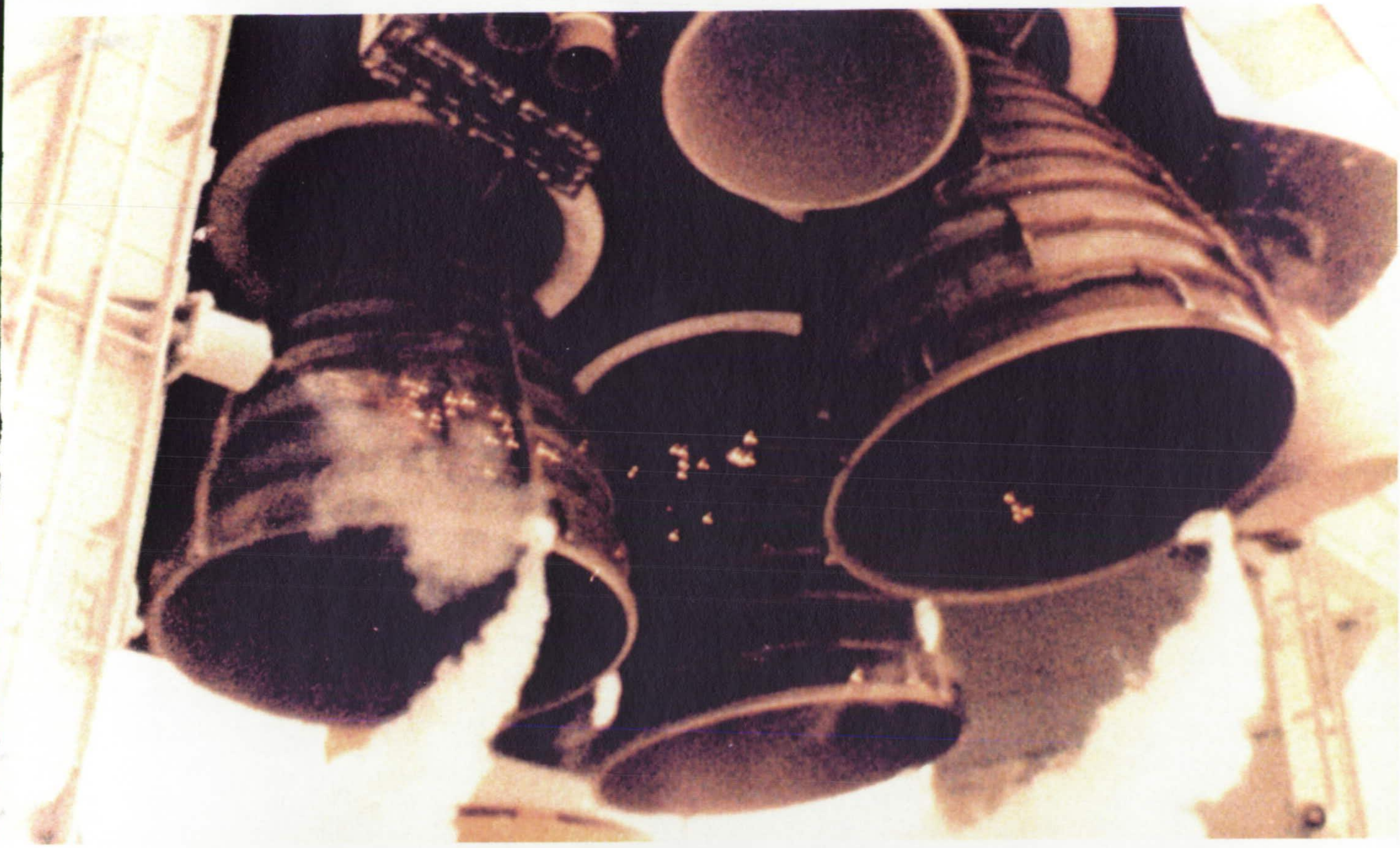
Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings (E-213, 222).

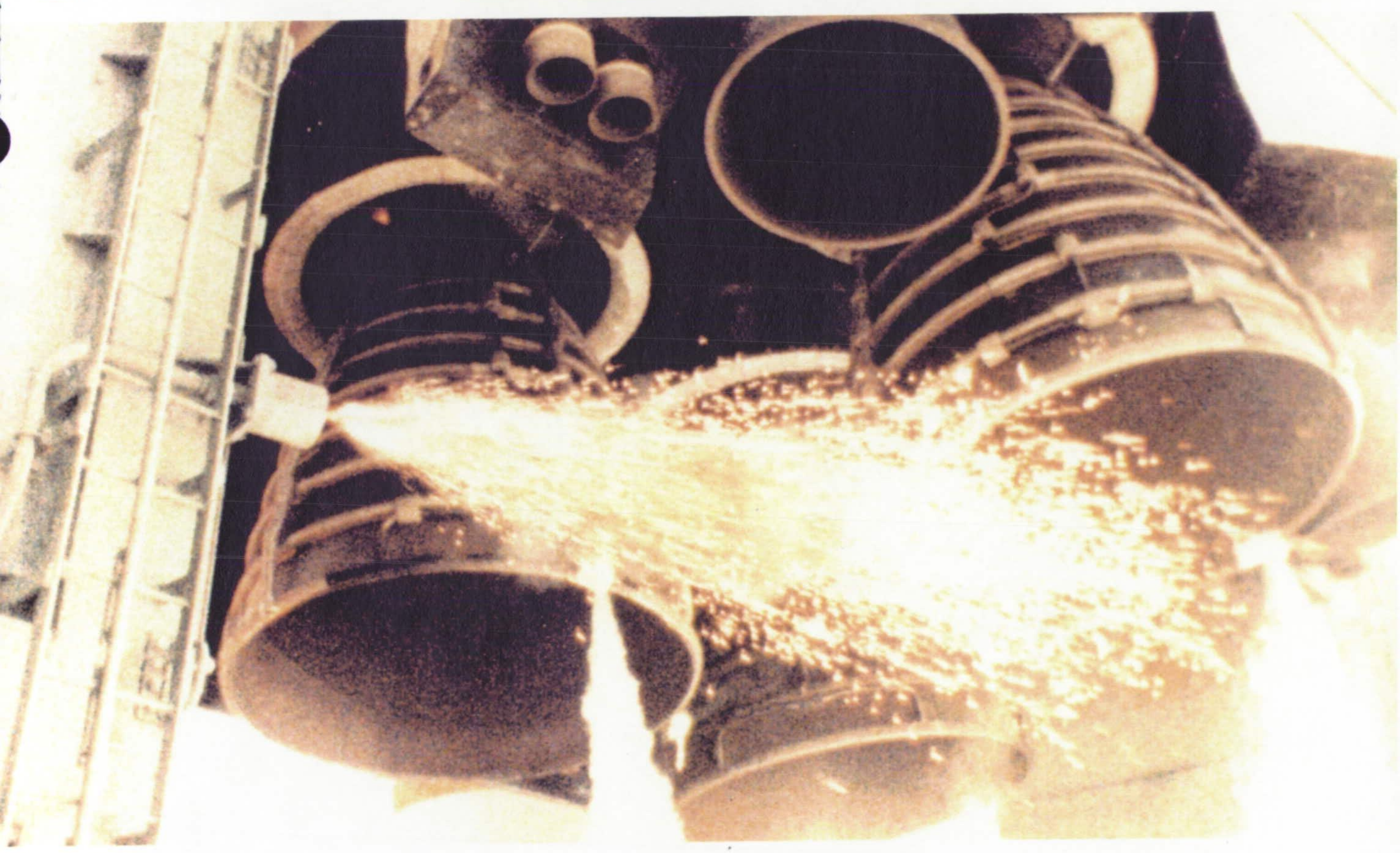
Orange flashes occurred in the SSME plume during ascent (ET-207, 208, E-207, 212, 220, 222).

Movement of the body flap was similar in amplitude and frequency to previous flights (E-207, 212, 220).

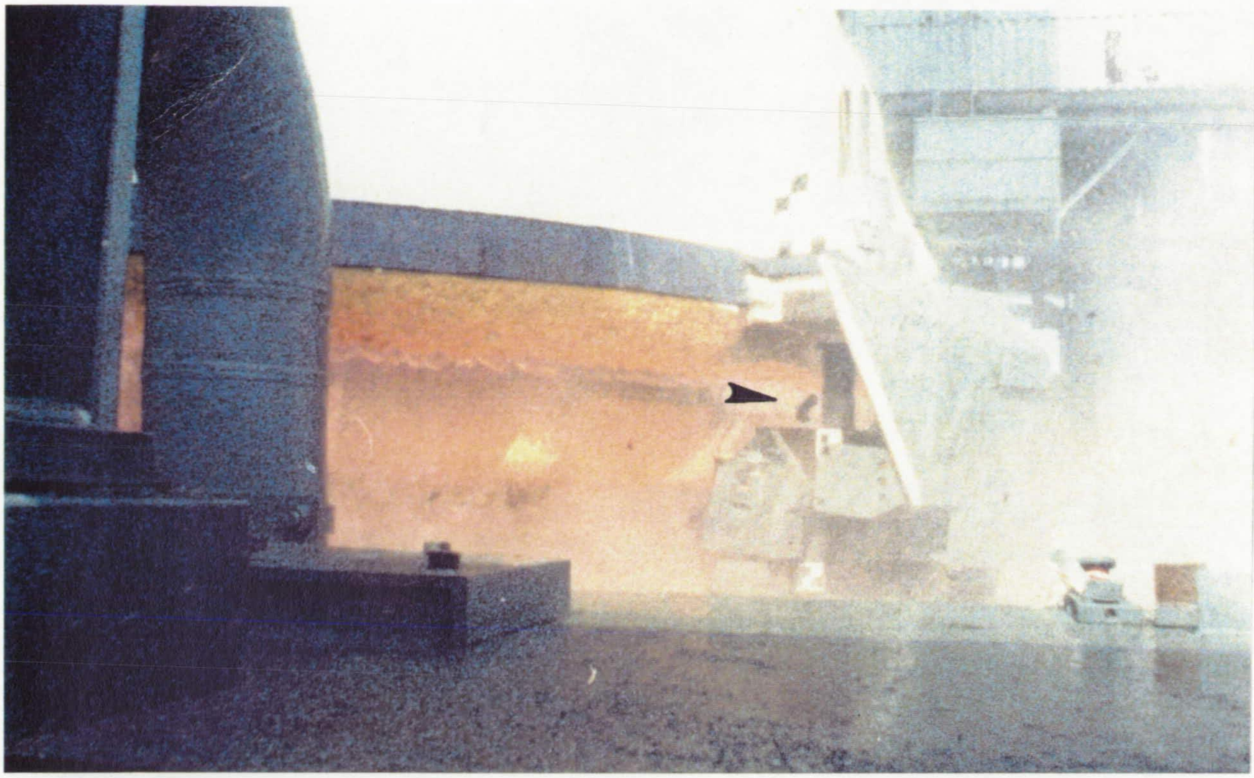
Aft dome charring, plume recirculation, and SRB separation appeared normal (TV-4B, TV-13, ET-204, ET-207, ET-208, ET-212, E-207, 208, 212).

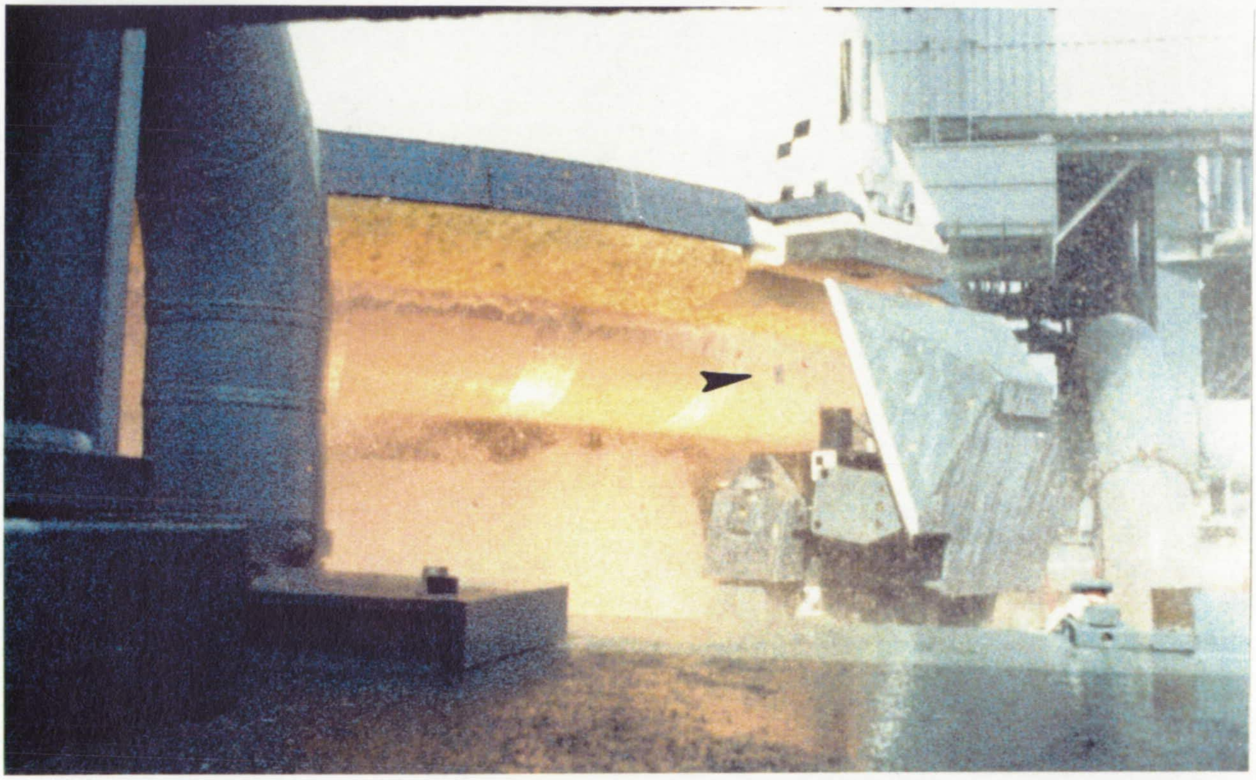
Frustum separation from the forward skirts, parachute deployment and reefing appeared normal. Nozzle severance debris was typical. Water splashdown was not visible (E-301, 302).





Normal initiation of hydrogen burn ignitor (top) compared to anomalous initiation of STS-46 ignitor (bottom). This ignitor malfunctioned with a faster activation, more concentrated stream of sparks, and was completely expended in 1.3 seconds (nominal burn time is 8 to 12 seconds).





A stud hang-up occurred on HDP #7. The stud remained fully extended as the aft skirt ascended. The stud pulled off three pieces of the EPON shim (arrow) before dropping into the holddown post.

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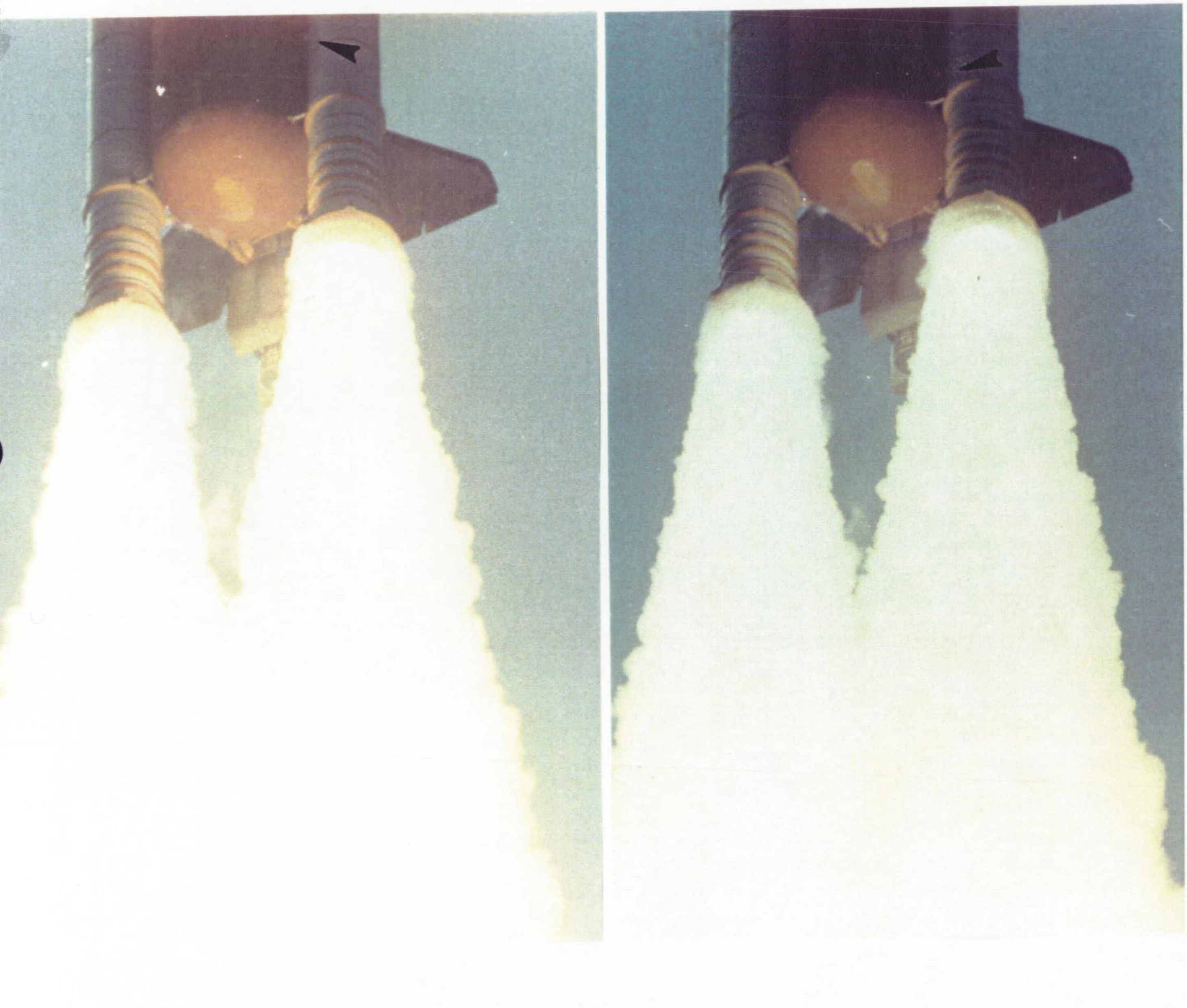


A light-colored, soft focused object first appeared against the LH SRB case and fell aft along the -Z side of the External Tank at 56:59.012 GMT in film item E-57. The origin of the object had not been determine.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

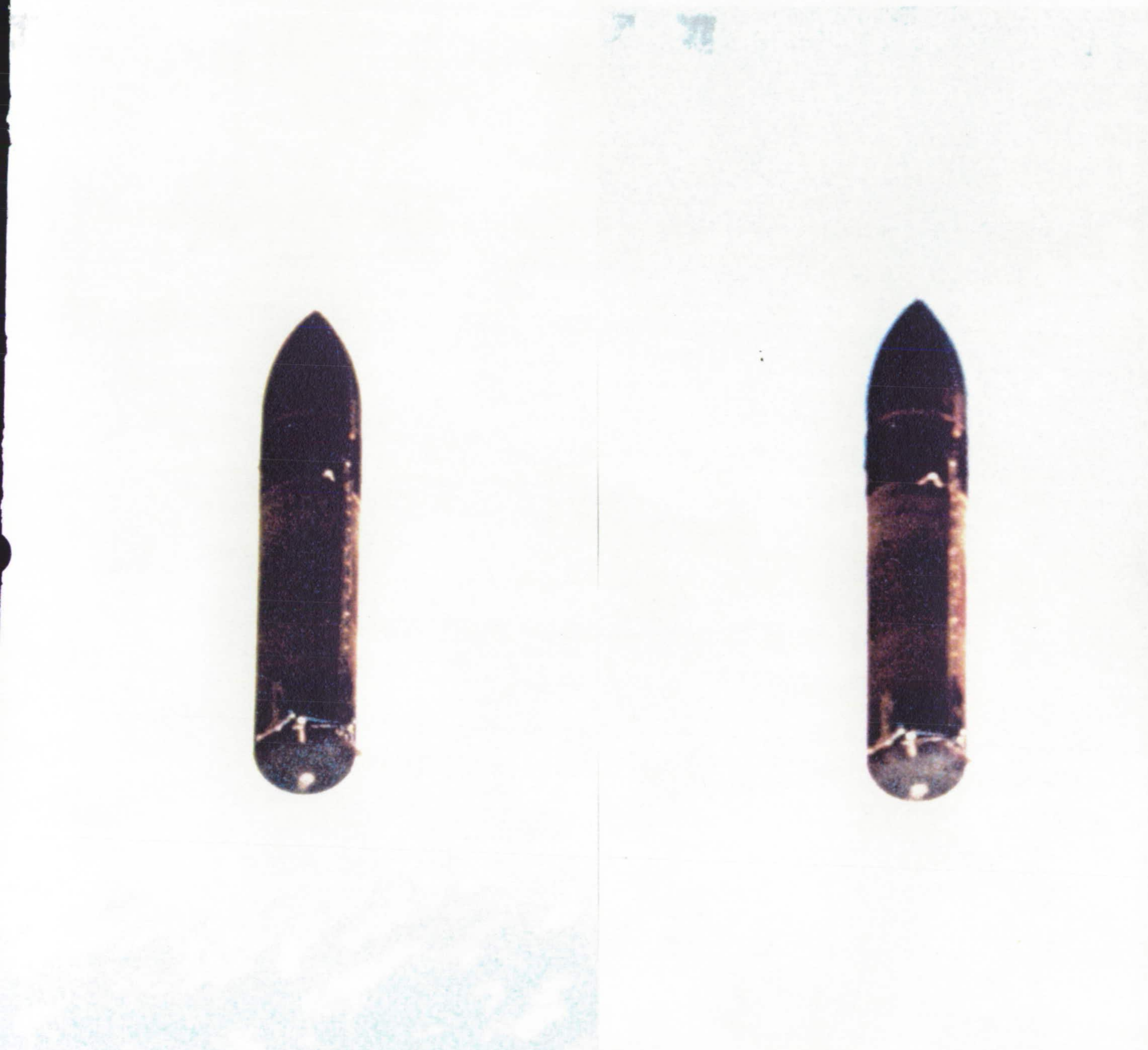
OV-104 was not equipped to carry ET/ORB umbilical separation cameras. Flight crew hand held photography of the External Tank after separation from the Orbiter (DTO-0312) was not planned for this mission. However, two views of the -Y+Z side of the ET were obtained 12 minutes after separation from the Orbiter.

There were no apparent anomalies on the LO2 tank, intertank, LH2 tank, and aft dome acreage TPS. Bright spots on the PAL ramp, bipods, pressurization line/cable tray ramps, -Y vertical strut, and EO-2 fitting were caused by reflected sunlight.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 24 film and video data items, which included nine videos, eight 16mm high speed films, and seven 35mm large format films, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Main landing gear deployment and touchdown was normal. Nose rotation and touchdown of the nose landing gear was smooth. No vehicle anomalies or major tile damage was visible in these views.



Views of the External Tank 12 minutes after separation from the Orbiter showed no anomalies on the LO2 tank, intertank, LH2 tank, and aft dome TPS acreage. Bright spots on the PAL ramp, bipods, pressurization line/cable tray ramps, EO fitting, and LH vertical strut were caused by reflected sunlight.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 3 August 1992 from 0800 to 1000 hours. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 10 MSA-2 debonds over fasteners and one area of missing TPS, which measured 2.5"x1.5", near the 381 ring frame between the +Y and +Z axes (Figure 4). Minor localized blistering of the Hypalon paint had occurred in isolated areas. All BSM aero heatshield covers were locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae were intact and undamaged. Minor blistering of the Hypalon paint occurred on the systems tunnel cover and forward ET/SRB attach point (Figure 5). No pins were missing from the frustum severance ring. The forward separation bolt and electrical cables appeared to have separated cleanly.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. No TPS was missing from the upper strut fairing. All three aft booster stiffener rings sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring had delaminated. The K5NA closeouts (protective domes) on the kick ring forward and aft fasteners had been eliminated. RTV-133 replaced the K5NA over the forward fasteners. The aft fasteners were uncovered. The aft skirt acreage TPS was in good condition (Figure 6).

All four Debris Containment System (DCS) plungers were properly seated. This was the ninth flight utilizing the optimized link. A 3-inch diameter piece of the HDP #3 EPON shim was missing prior to water impact (sooted/charred substrate).

Figure 4. **RIGHT SRB FRUSTUM**

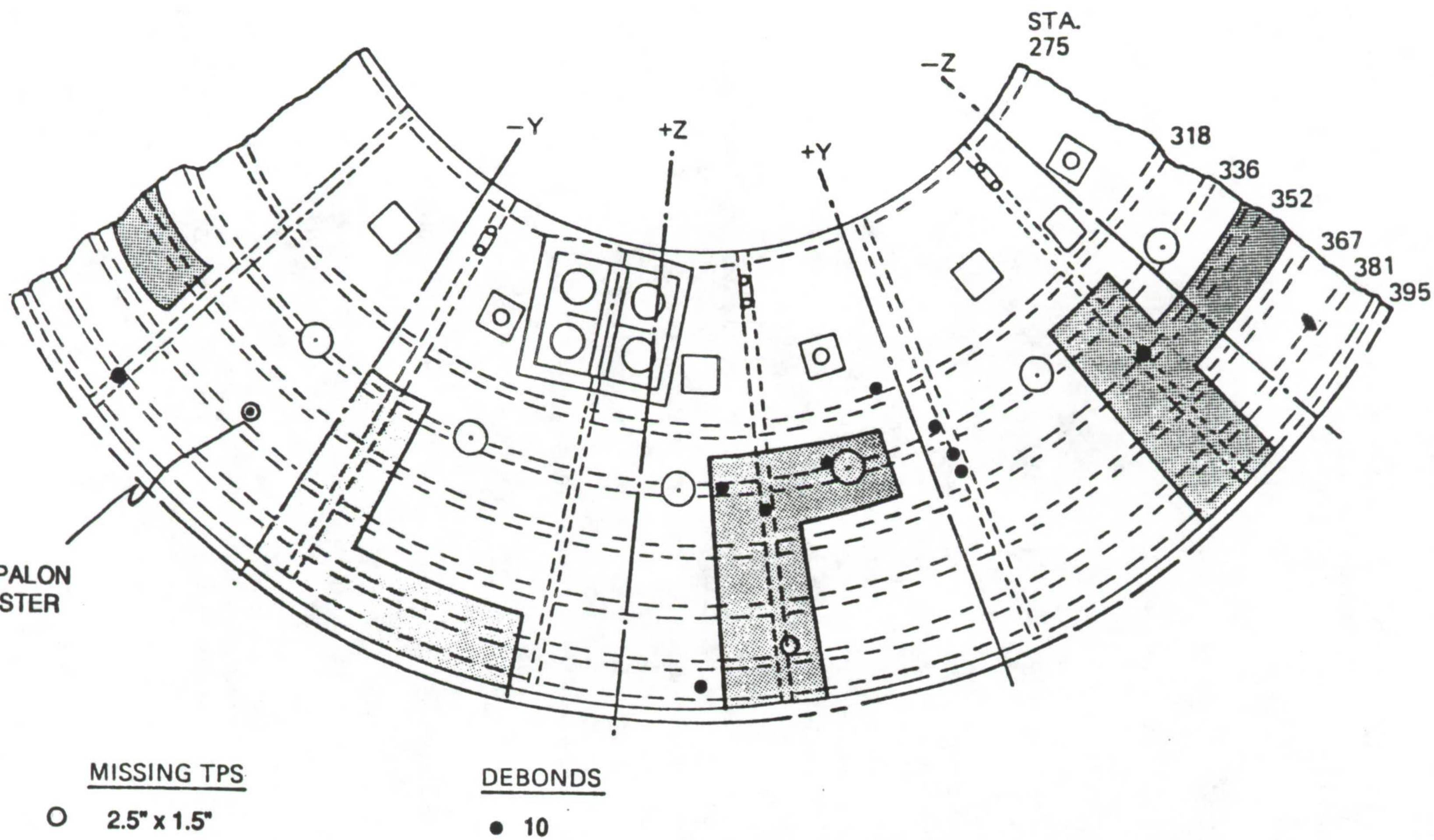
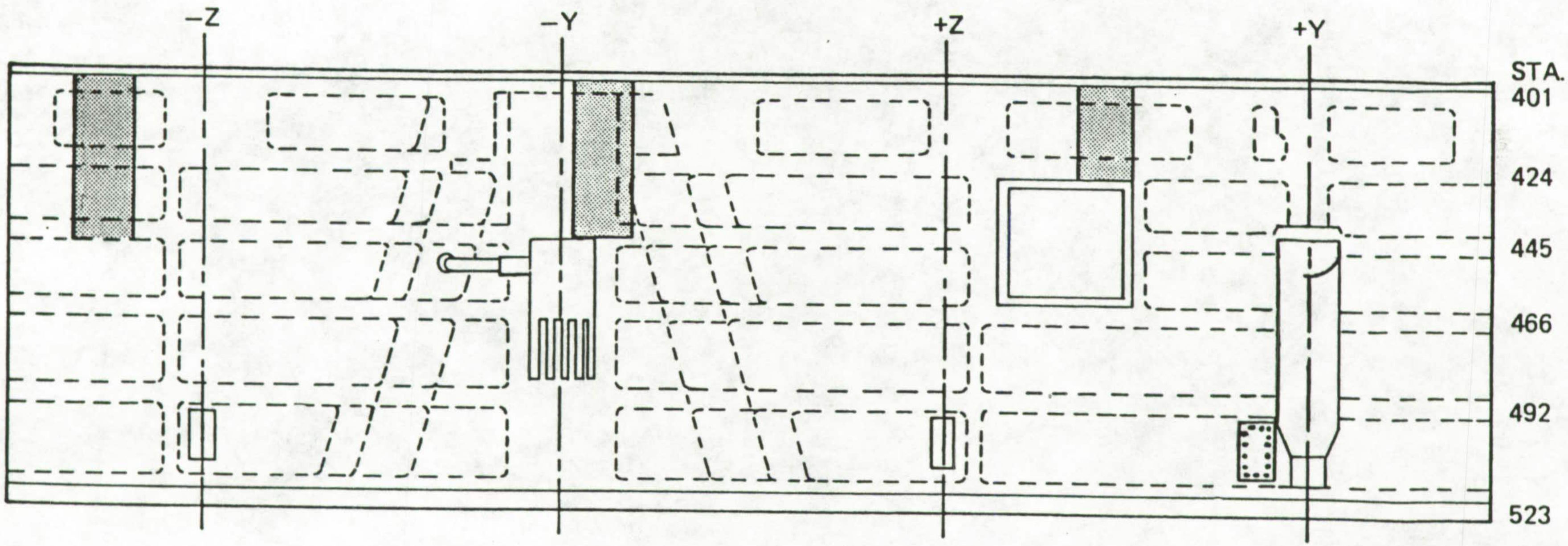


Figure 5. **RIGHT SRB FWD SKIRT**



TPS MISSING

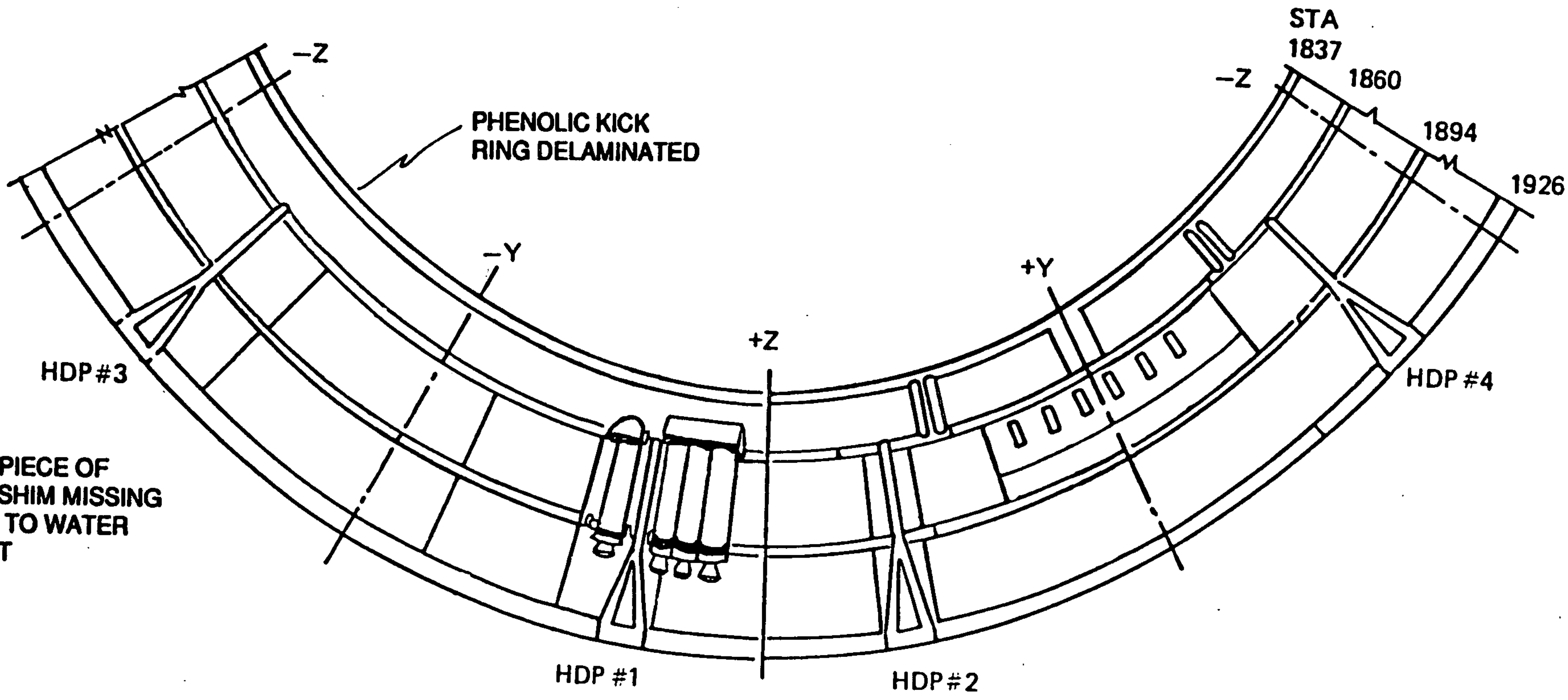
NONE

DEBONDS

NONE

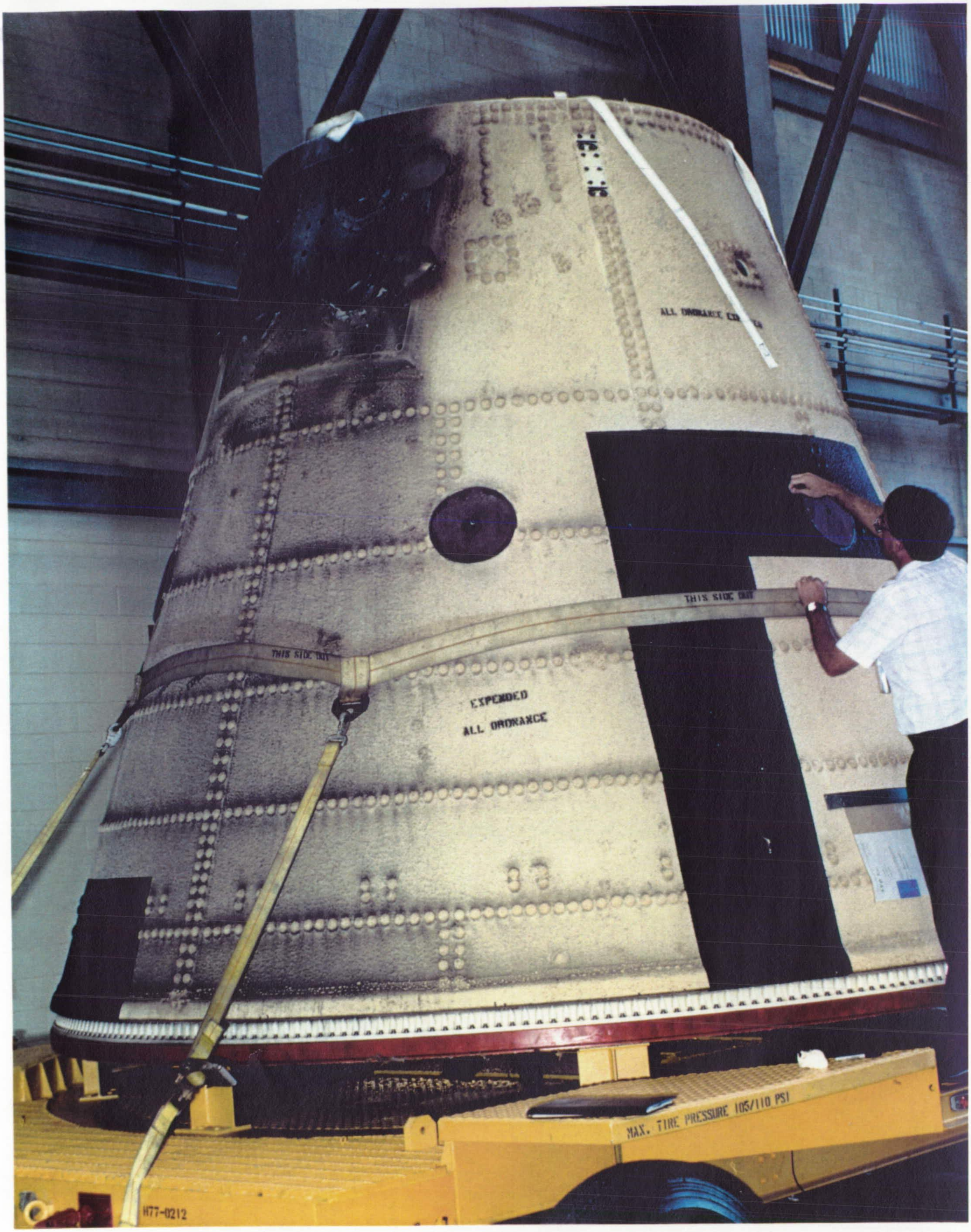
MINOR BLISTERING OF
HYPALON PAINT ON
SYSTEMS TUNNEL COVER
AND ET/SRB ATTACH POINT

Figure 6. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



3" DIA PIECE OF EPON SHIM MISSING PRIOR TO WATER IMPACT

ALL DCS PLUNGERS SEATED PROPERLY



The RH frustum had 10 MSA-2 debonds over fasteners and one area of missing TPS near the 381 ring frame between the +Y and +Z axes. All BSM aero heat shield covers were locked in the fully opened position.

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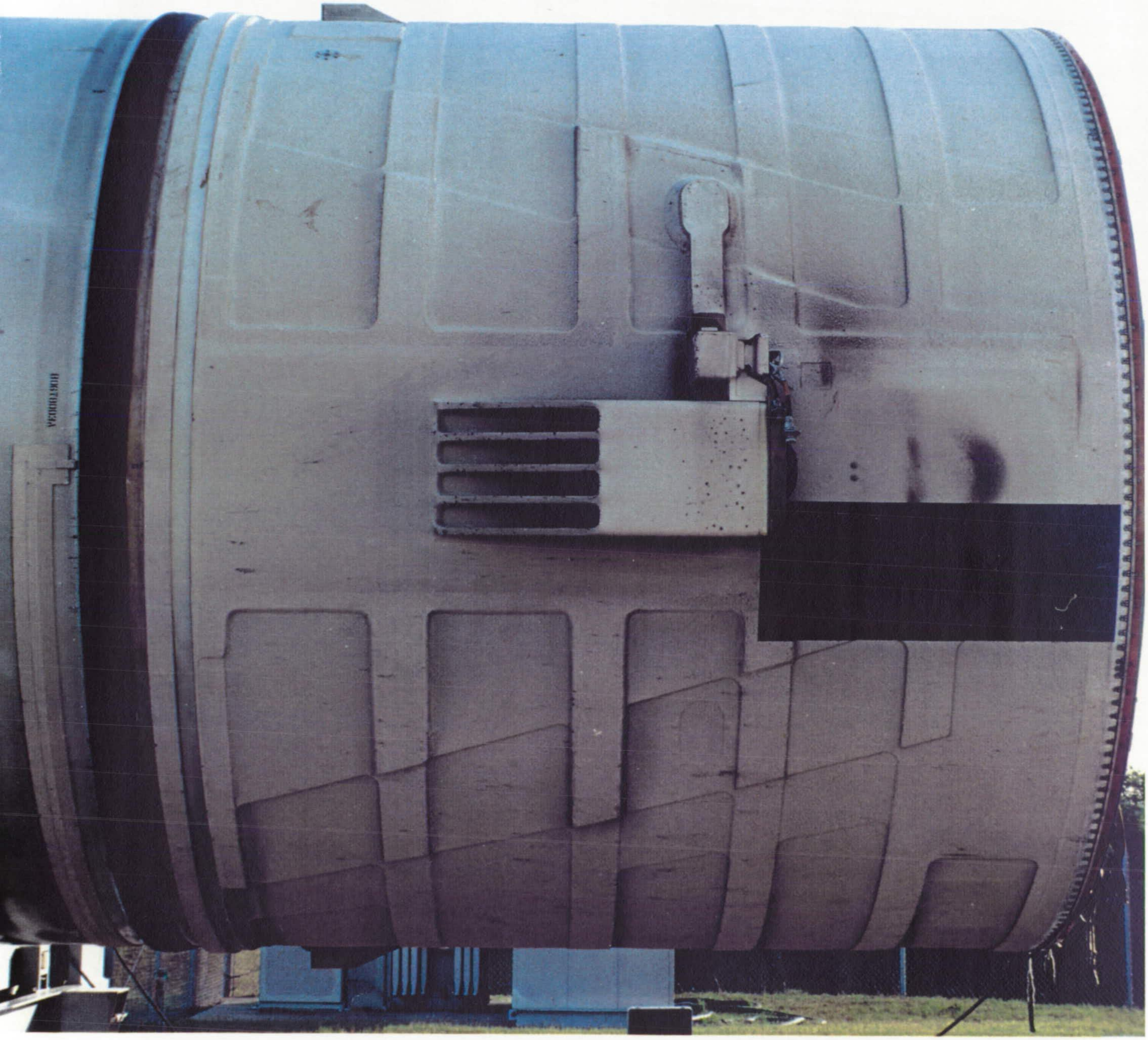


The RH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred in localized areas. Both RSS antenna covers/TPS were intact and undamaged.

Post flight condition of the SRM segment cases, factory joints, and field joint closeouts

Post flight condition of the RH aft booster. The aft skirt acreage TPS was sooted but in good condition. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage.

A 3-inch diameter piece of the HDP #3 EPON shim was missing prior to water impact (sooted/charred substrate).

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 12 MSA-2 debonds over fasteners. There was very minor localized blistering of the Hypalon paint in isolated areas. The BSM aero heatshield covers were locked in the fully opened position (Figure 7).

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred around the ET/SRB attach point (Figure 8).

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. A 2"x1" area of TPS was missing from the upper strut fairing and may have been lost during separation. The IEA, IEA covers, and all three aft booster stiffener rings sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring had delaminated. The K5NA closeouts (protective domes) on the forward and aft fasteners on the kick ring had been eliminated (Figure 9). RTV-133 replaced the K5NA over the forward fasteners. The aft fasteners were uncovered. The aft skirt acreage TPS was in good condition.

The HDP #7 stud hole was broached due to a stud hang-up at lift off as observed in the launch films. Small pieces of the EPON shim material adjacent to the stud hole had been pulled off by the stud. All four Debris Containment System (DCS) plungers were properly seated. This was the ninth flight utilizing the optimized link. None of the remaining EPON shim material was lost prior to water impact.

Figure 7. **LEFT SRB FRUSTUM**

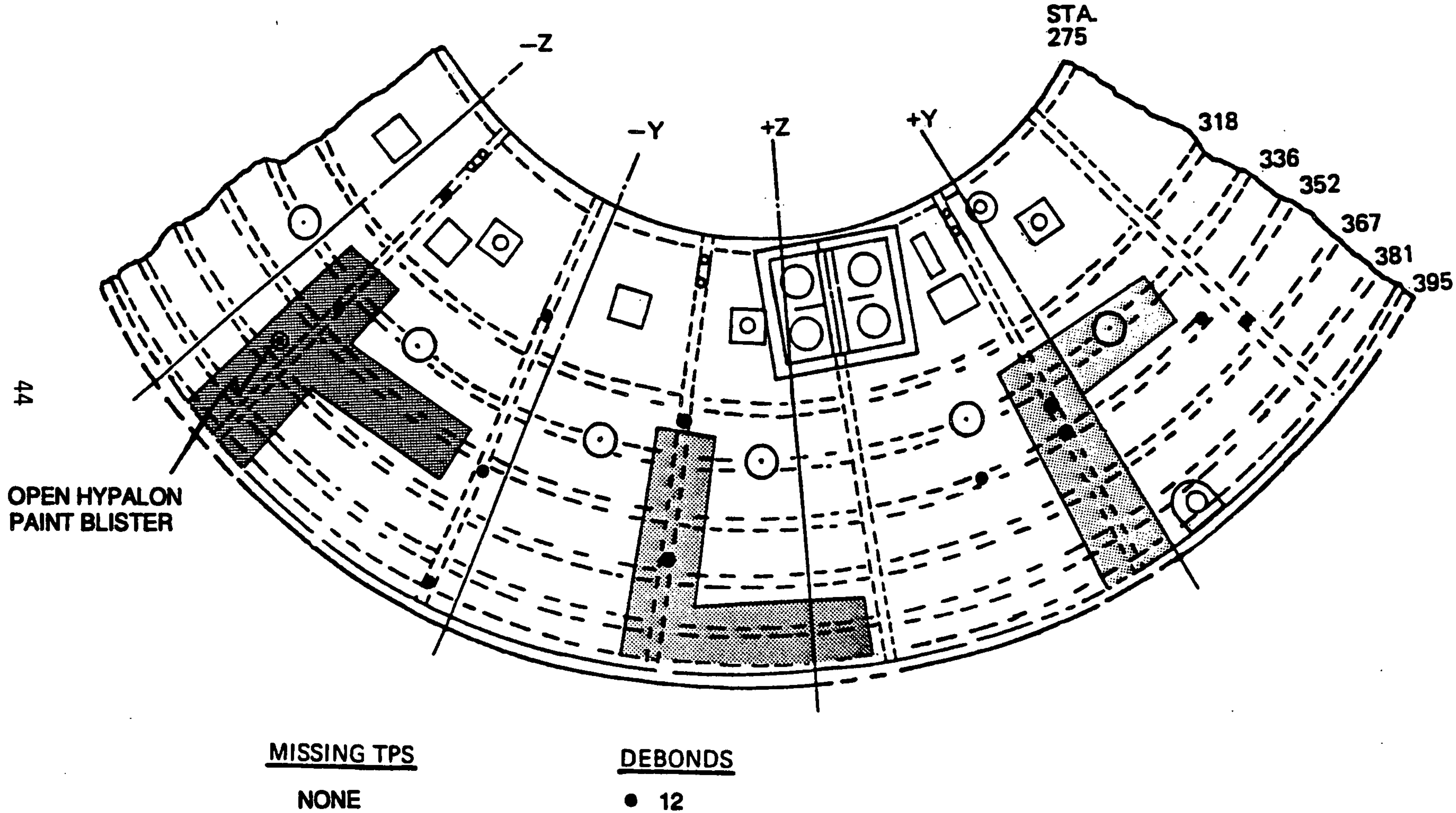
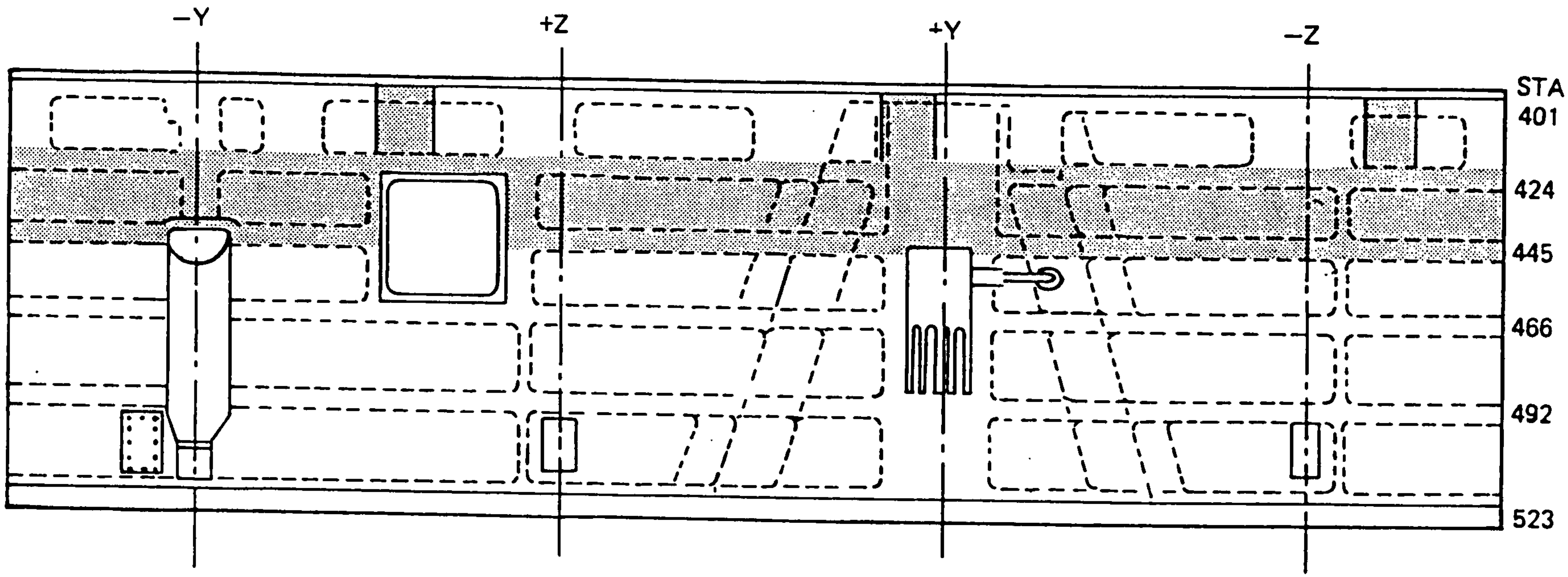


Figure 8. **LEFT SRB FWD SKIRT**



TPS MISSING

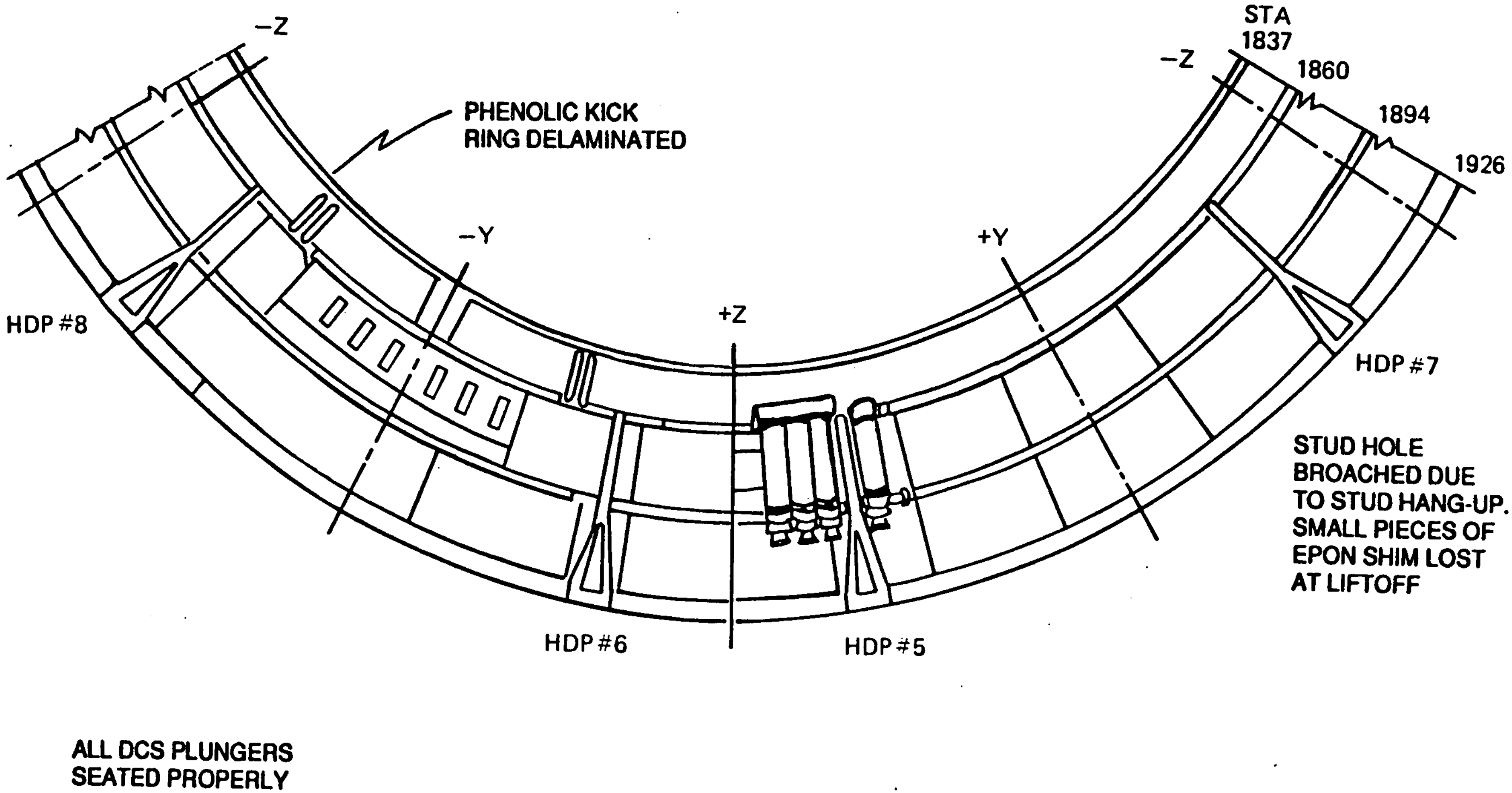
NONE

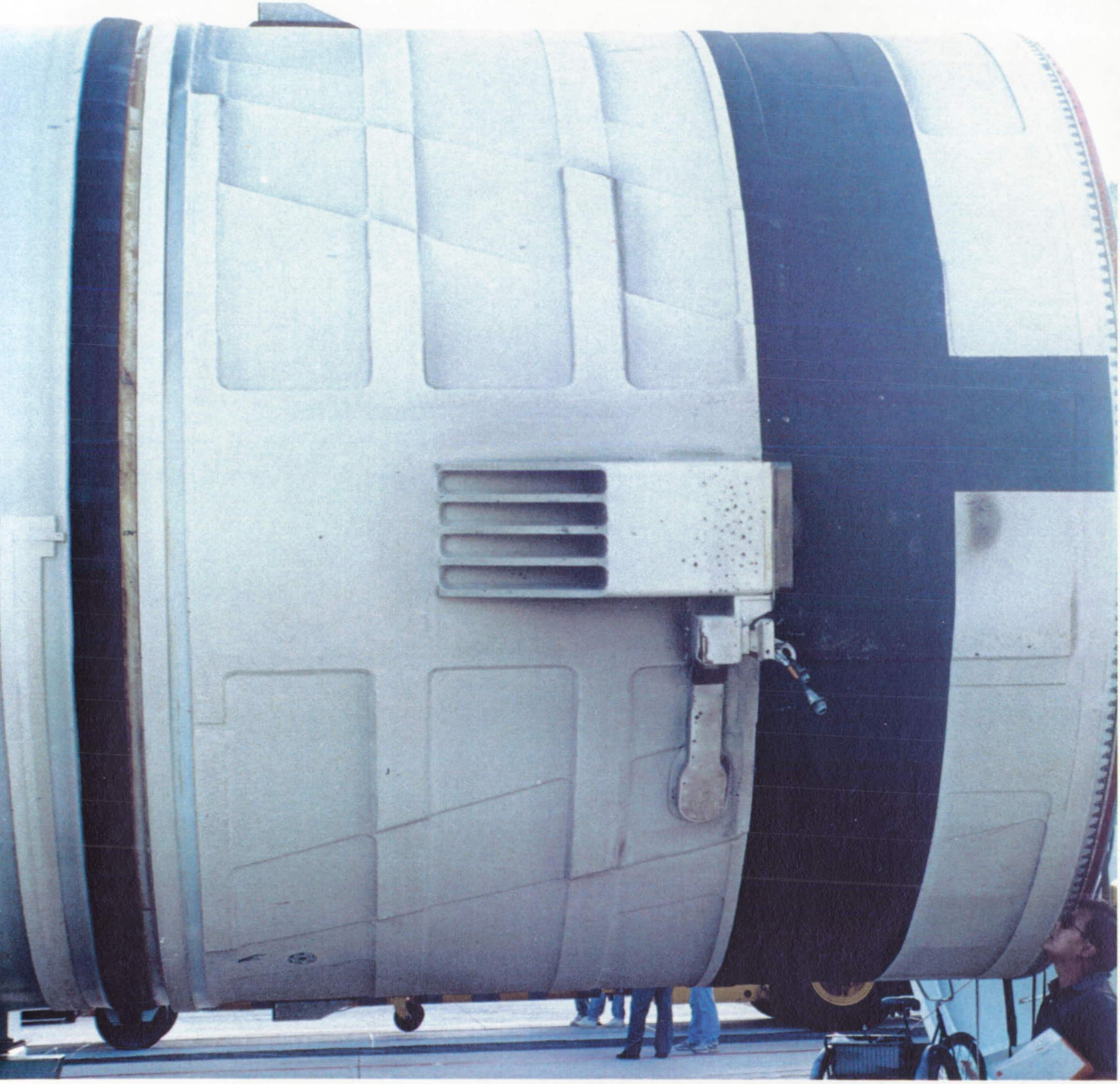
DEBONDS

NONE

MINOR BLISTERING OF
HYPALON PAINT ON
ET/SRB ATTACH FITTING

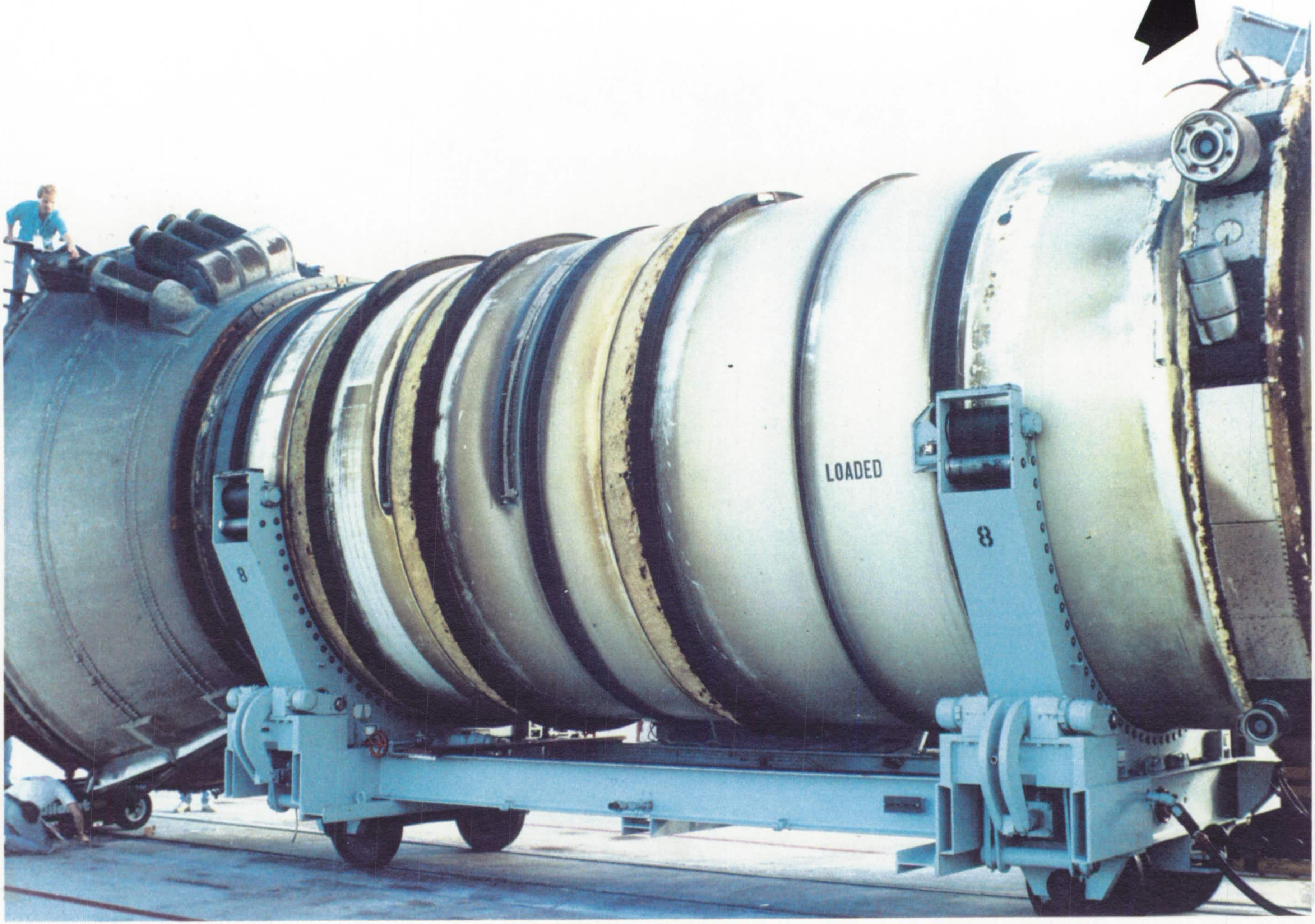
Figure 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**





The LH forward skirt exhibited no MSA-2 debonds or missing TPS.
Both RSS antenna covers/TPS were intact and undamaged.

Post flight condition of the SRM segment cases, factory joints, and field joint closeouts



Post flight condition of the LH aft booster. The aft skirt acreage TPS was sooted but in good condition. Note water impact damage to the ETA ring and IEA.

Close-in view of water impact damage to the ETA ring, IEA, and IEA covers. This type of damage was not a debris concern.

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The HDP #7 stud hole was broached due to a stud hang-up at lift off. Small pieces of the EPON shim material adjacent to the stud hole had been pulled off by the stud.

6.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 99 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	95	99
2	99	94	99
3	99	99	99
4	99	97	99
5	99	98	99
6	99	94	99
7	99	96	99
8	99	96	99

STS-46 was the ninth flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris.

SRB Post Launch Anomalies are listed in Section 9.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-104 (Atlantis) was conducted on 8-9 August 1992 at the Kennedy Space Center on Shuttle Landing Facility (SLF) Runway 33 and in the Orbiter Processing Facility bay #2 to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 236 hits, of which 22 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 33 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates that the total number of hits is greater than average and the number of hits one inch or larger is average. Figures 10-13 show the TPS debris damage assessment for STS-46.

The Orbiter lower surface sustained a total of 186 hits, of which 11 had a major dimension of one inch or greater. Seventy-one hits, two of which had a major dimension of one inch or greater, were clustered aft and inboard of the LH2 ET/ORB (LH) umbilical. Similar clusters of hits have been observed in this area on previous flights and are attributed to ice/debris impacts during ET separation and/or damage from purge barrier baggie and ice during ascent. The distribution of the remaining hits on the Orbiter lower surface does not point to a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

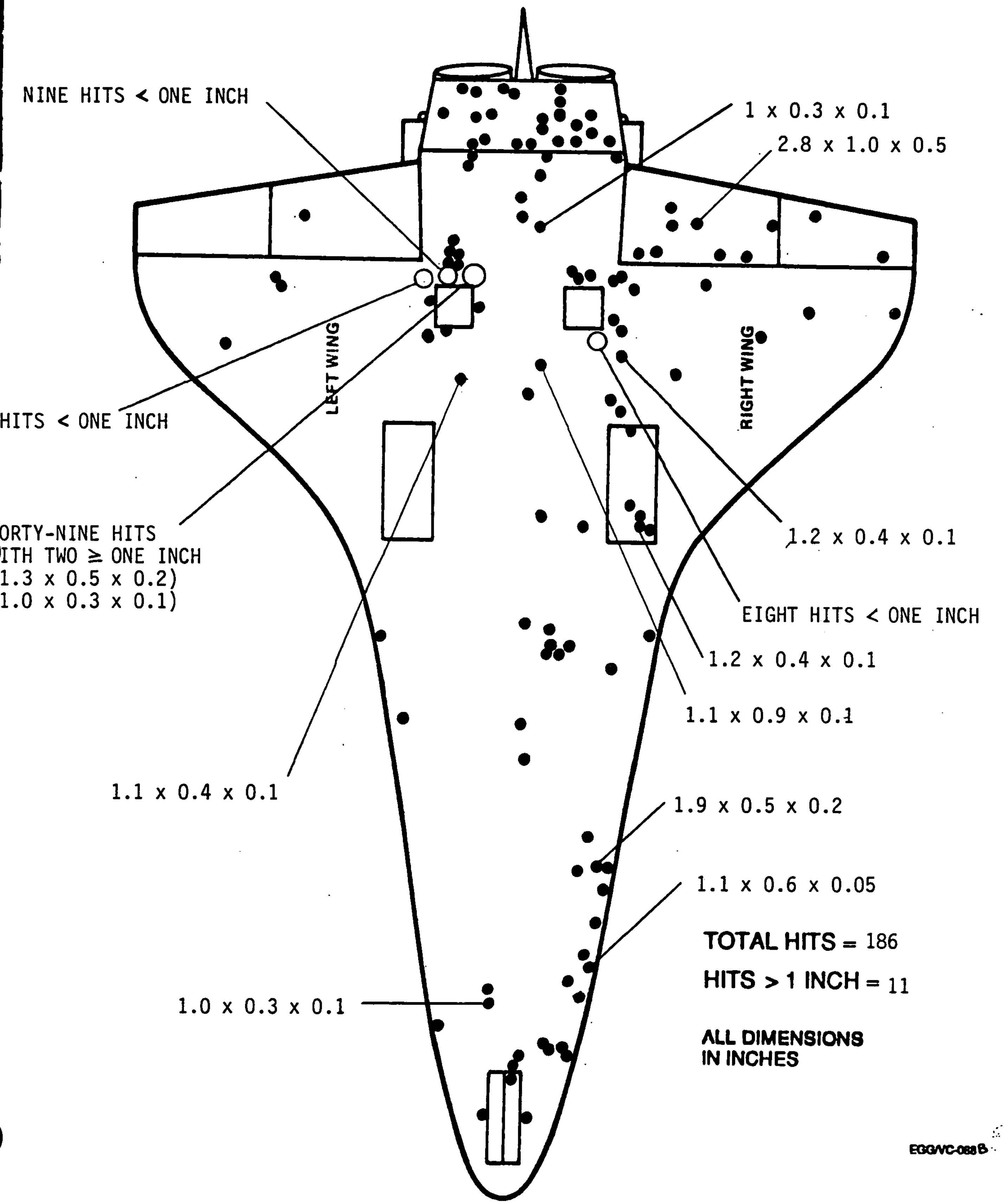
The following table breaks down the STS-46 Orbiter debris damage by area:

Lower surface	11	186
Upper surface	0	8
Right side	0	1
Left side	0	1
RH OMS Pod	7	21
LH OMS Pod	4	19
TOTALS	22	236

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in excellent condition for a landing on the KSC runway.

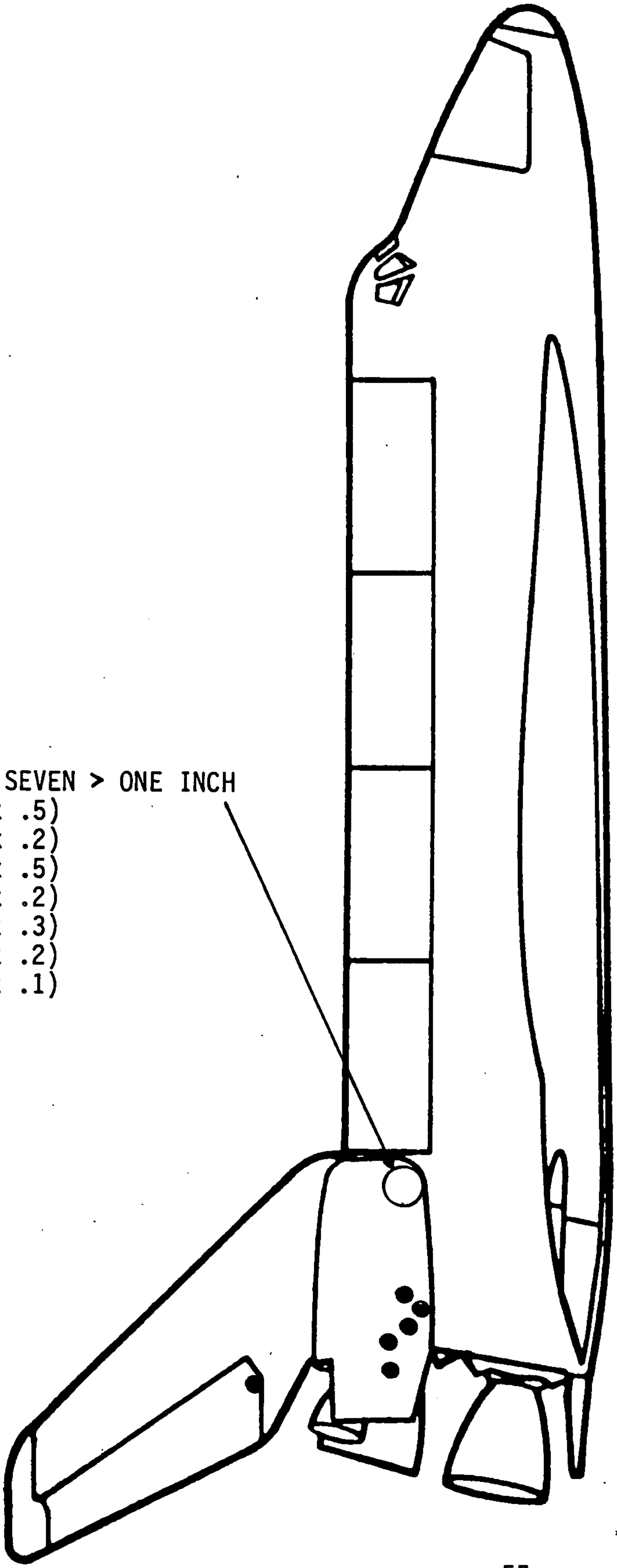
All ET/Orbiter (EO) separation ordnance devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

Figure 10. **DEBRIS DAMAGE LOCATIONS**



STS-46

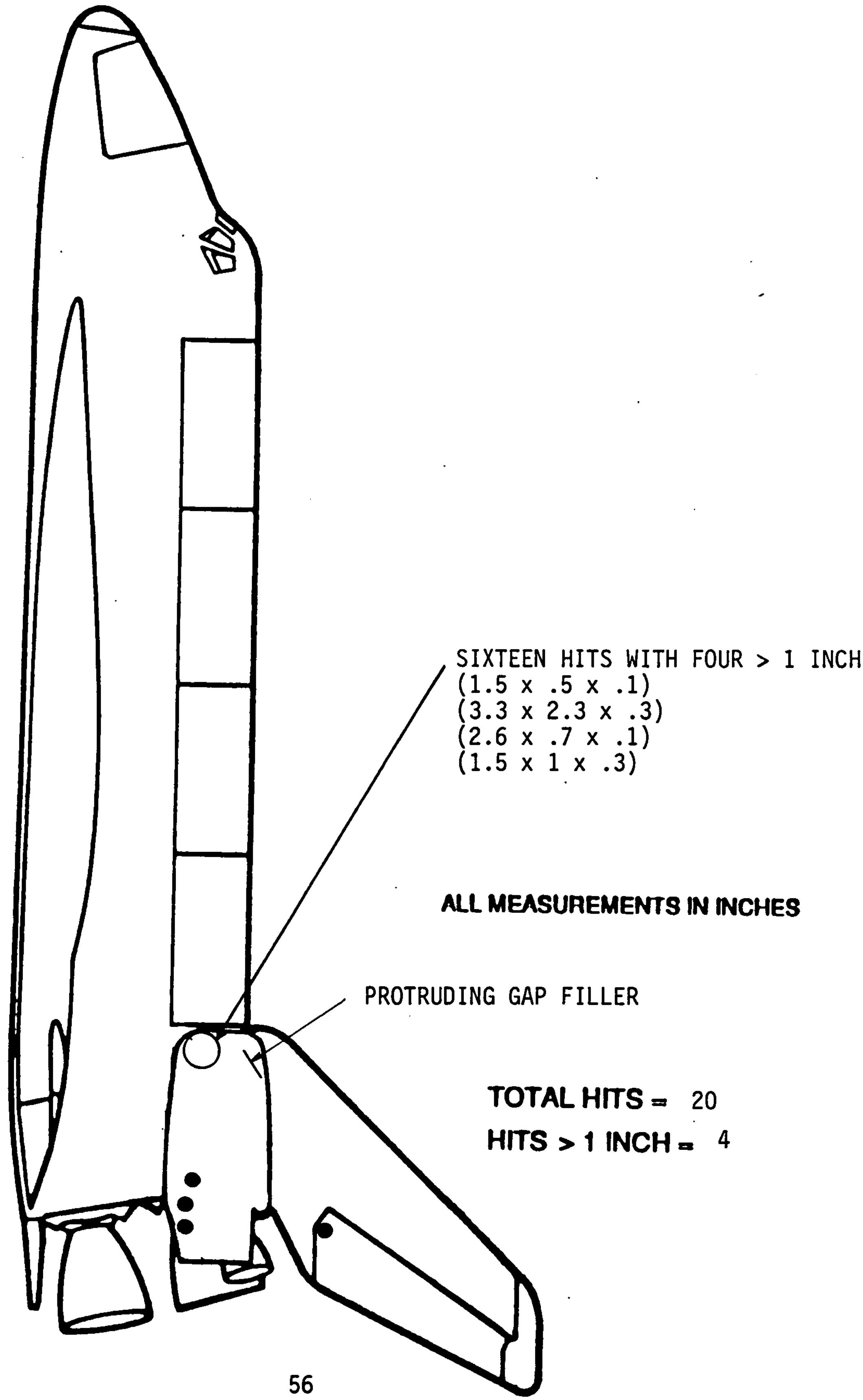
Figure 11. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 17

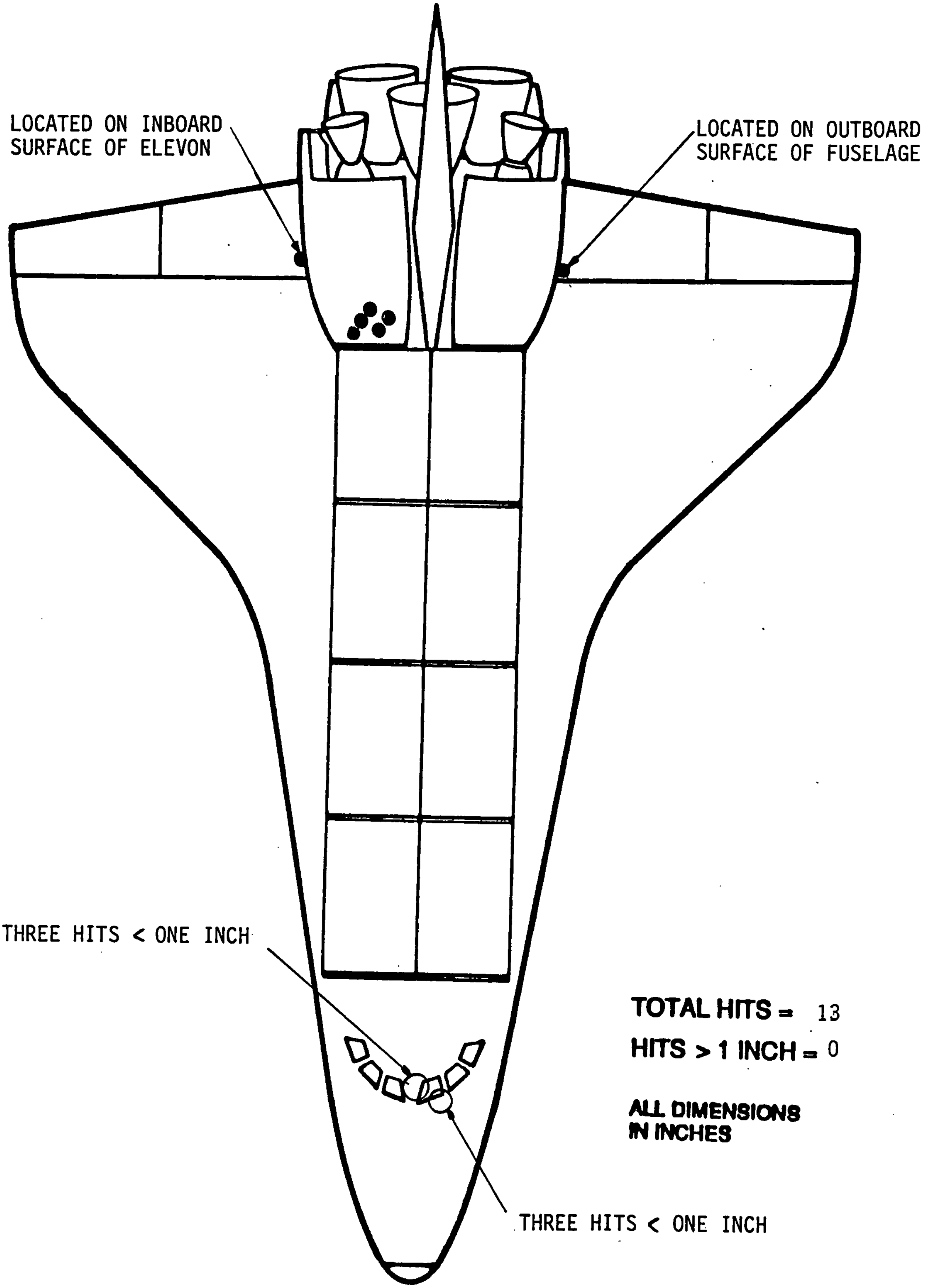
HITS > 1 INCH = 7

Figure 12. **DEBRIS DAMAGE LOCATIONS**



STS-46

Figure 13. DEBRIS DAMAGE LOCATIONS



Damage to the base heat shield tiles was typical. The SSME #1 Dome Mounted Heat Shield (DMHS) closeout blanket was torn at the 6:00 o'clock position. The blanket on SSME #2 was frayed from the 2:00 to 3:00 position. There was no apparent damage to the SSME #1 nozzle insulation from the hydrogen ignitor anomaly during SSME ignition.

There was no visible damage to the RCC nosecap or wing leading edge panels.

Orbiter windows #3 and #4 exhibited moderate hazing with a few streaks. Hazing on the other windows was less than usual. Laboratory analysis will be performed on samples taken from the windows (reference Figure 14). Six damage sites were noted on the perimeter tiles around window #3. The impact sites were only surface coating losses or were no more than 1/4 inch deep. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles or by exhaust products from the SRB booster separation motors.

Runway 33 was inspected and swept by KSC EG&G SLF personnel on 7 August 1992 and all potentially damaging debris was removed. A post landing inspection of Runway 33 was performed immediately after landing. No debris or flight hardware was found.

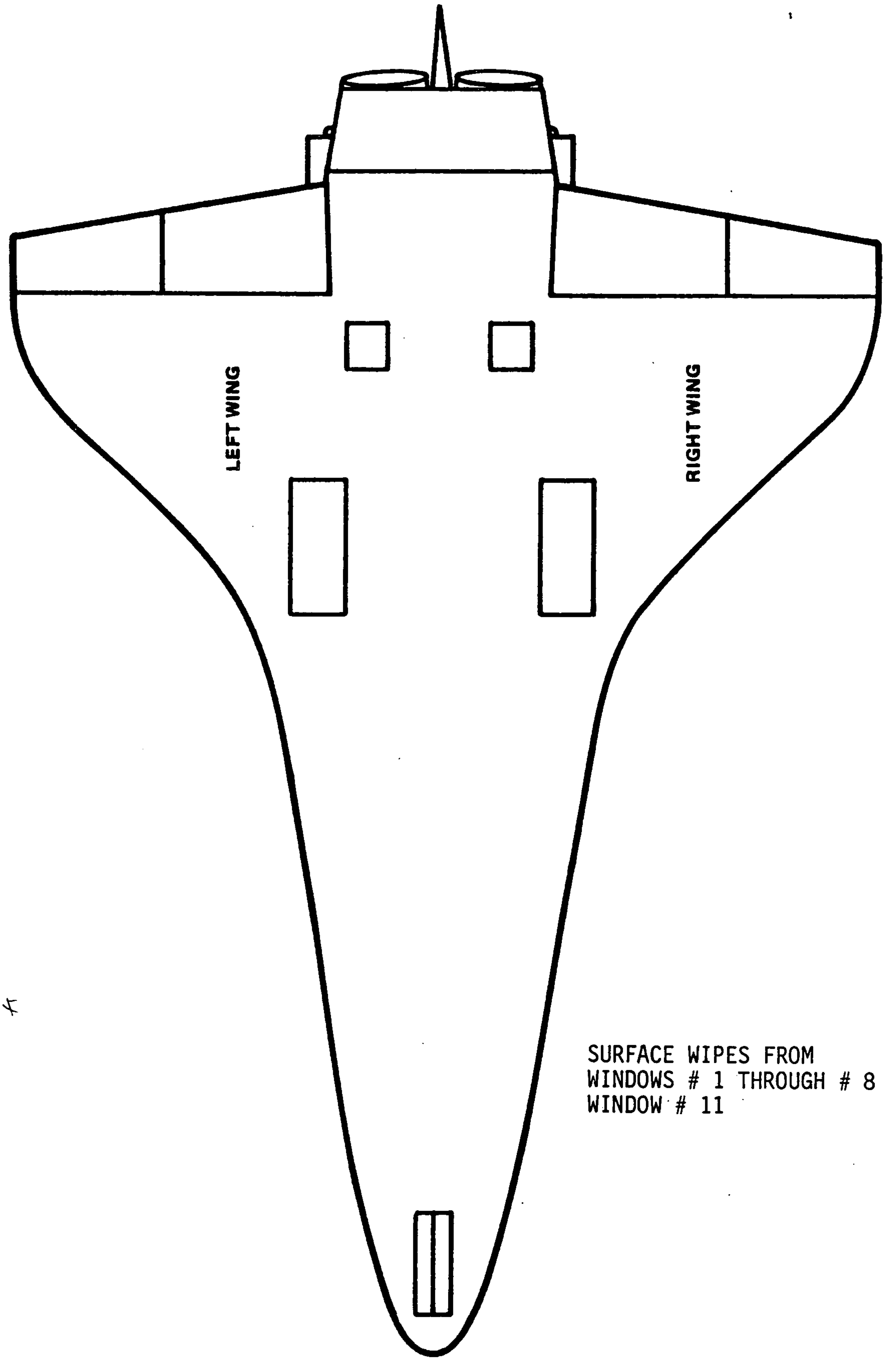
A portable Shuttle Thermal Imager (STI) was used to measure the surface temperatures of three areas on the Orbiter TPS after landing (per OMRSD V09AJ0.095). Twenty-two minutes after landing the Orbiter nosecap RCC was 194 degrees F, the RH wing leading edge RCC panel #9 was 139 degrees F, and panel #17 was 129 degrees F (reference Figure 15).

In summary, the total number of Orbiter TPS debris hits was greater than average and the number of hits with a major dimension one inch or larger was average when compared to previous flights (reference Figures 16-18).

Orbiter Post Launch Anomalies are listed in Section 9.

STS-46

Figure 14. **CHEMICAL SAMPLE LOCATIONS**



SURFACE WIPES FROM
WINDOWS # 1 THROUGH # 8 AND
WINDOW # 11

EGG/VC-088 D

Figure 15. **STS- 46 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

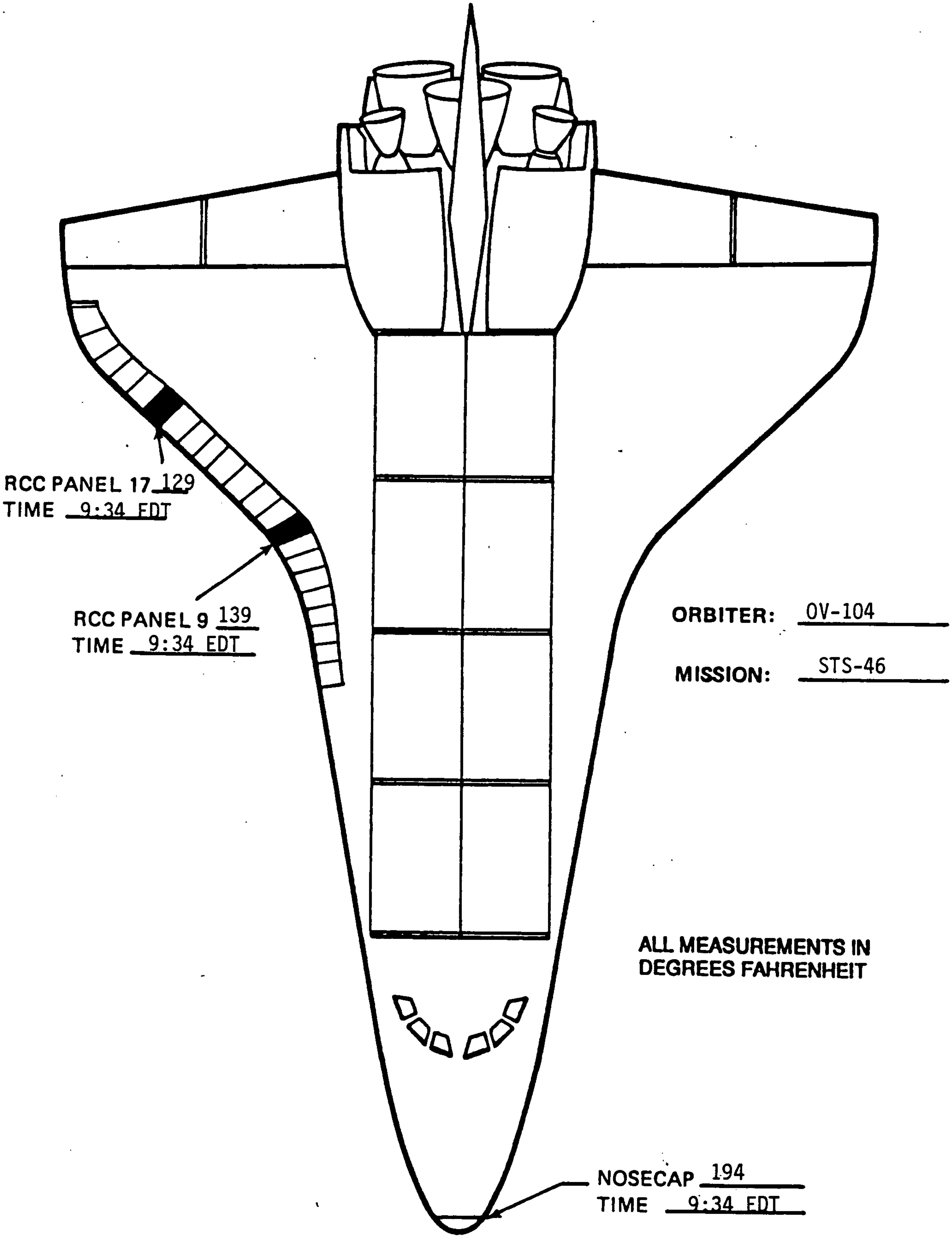


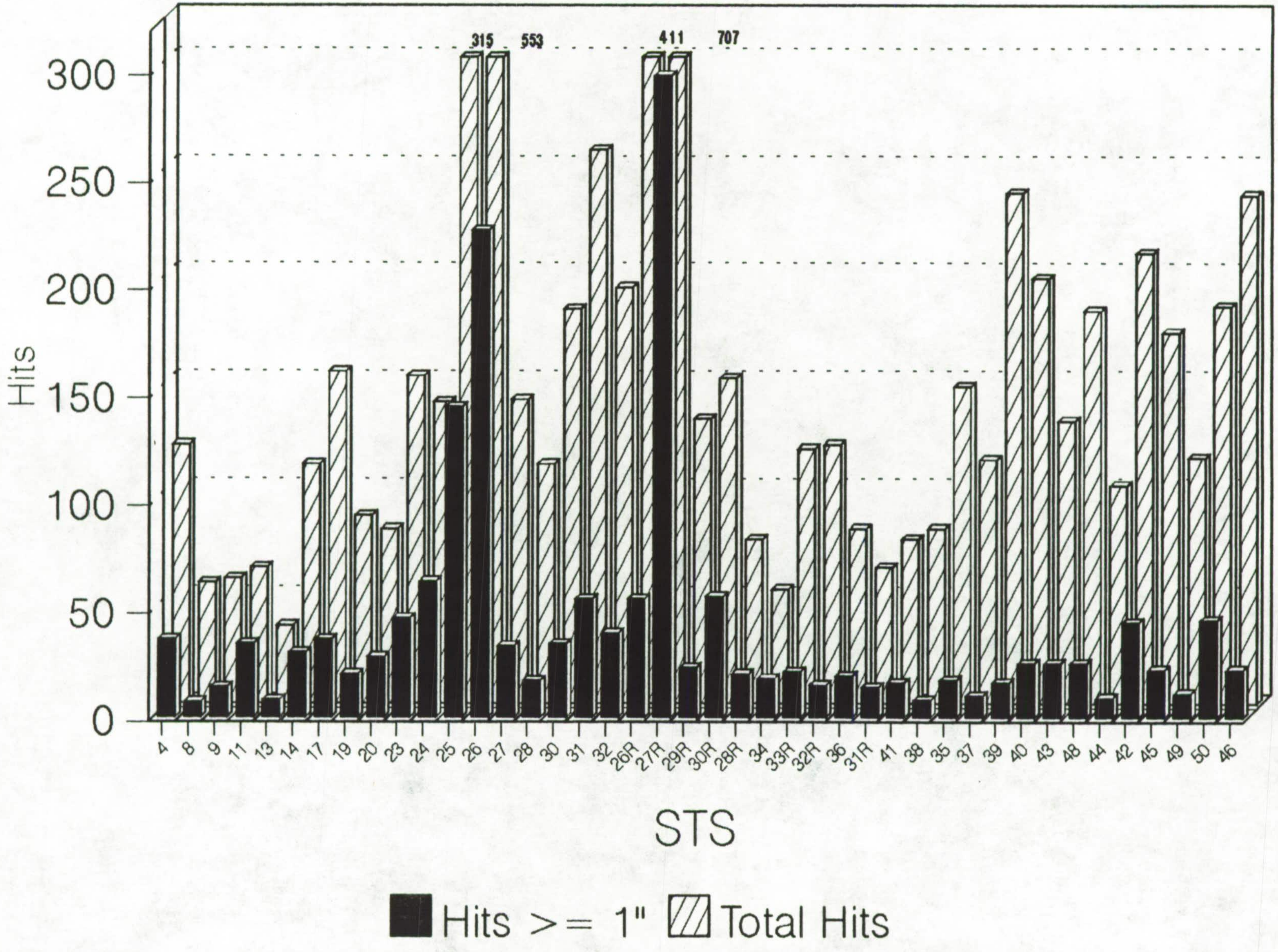
FIGURE 16: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
AVERAGE	15.5	88.8	22.7	122.1
SIGMA	7.5	44.3	11.3	54.3
STS-46	11	186	22	236

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

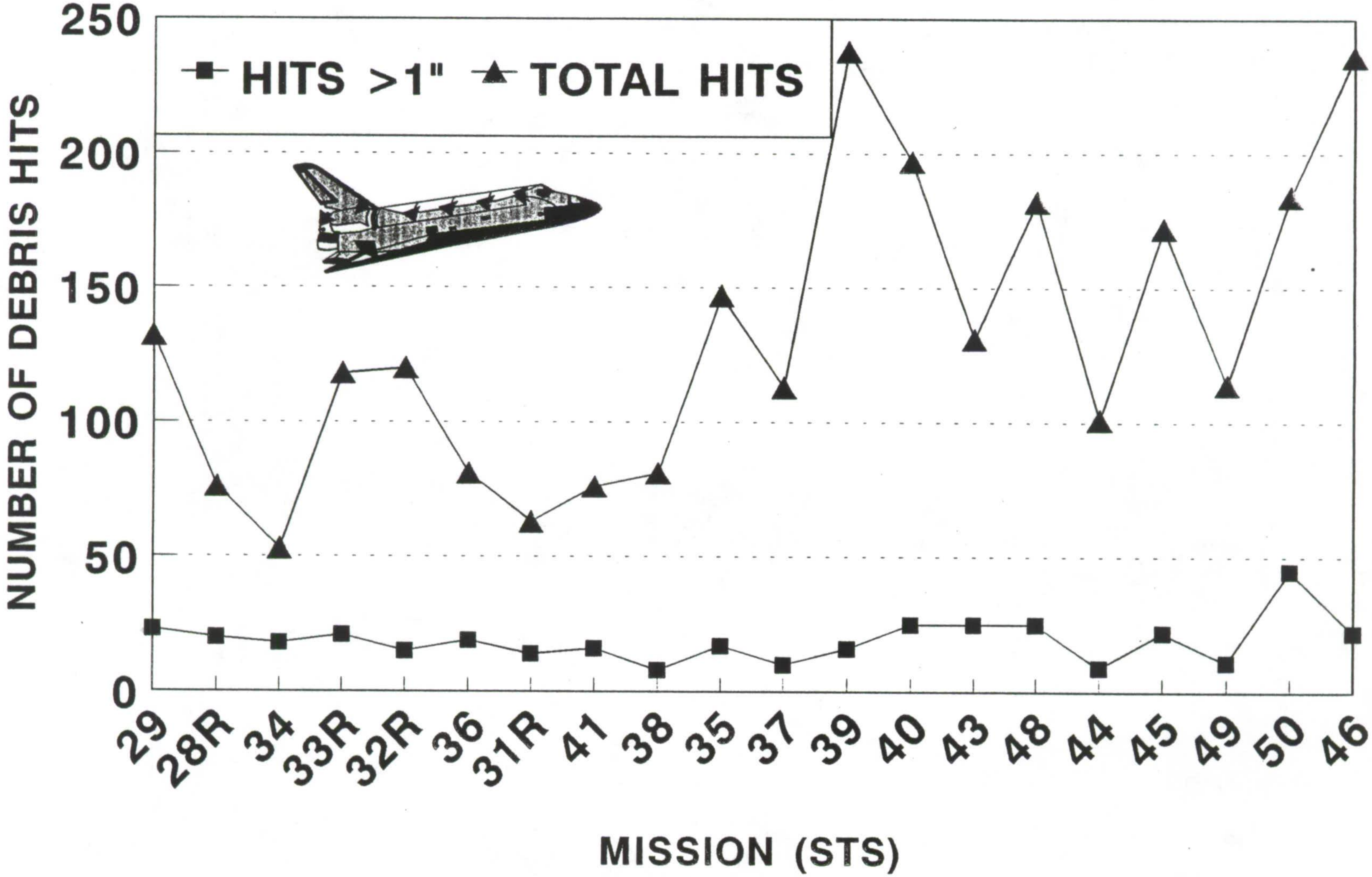
COMPARISON TABLE

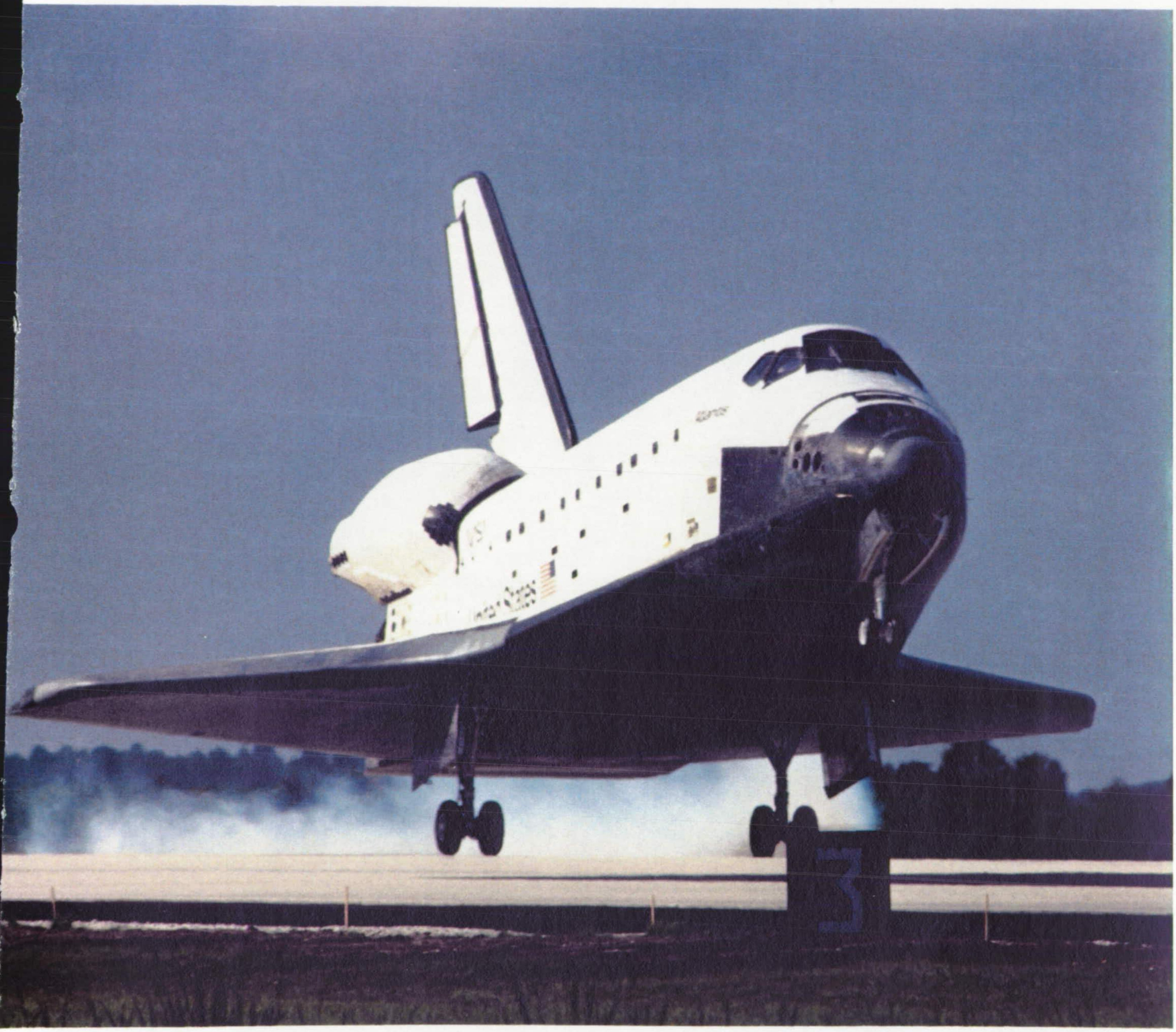
Figure 17.



ORBITER TPS DEBRIS DAMAGE
STS-29 THROUGH STS-46

Figure 18.





OV-104 Atlantis landed on Runway 33 at the Kennedy Space Center Shuttle Landing Facility on 8 August 1992

Overall view of Orbiter left side

Overall view of Orbiter right side

Overall view of the LO2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.

Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.

Orbiter windows #3 and #4 exhibited moderate hazing with a few streaks. Hazing on the other windows was less than usual.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of 9 samples were obtained from OV-104 (Atlantis) during the STS-45 post landing debris assessment at Kennedy Space Center (reference Figure 14). The nine submitted samples consisted of 8 window wipes (Windows 1-8) and 1 wipe from the Orbiter crew hatch window (Window 11). The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves the placing and correlating of particles with respect to composition, thermal (mission) effects, and availability. Debris sample results and analyses are listed by Orbiter location in the following summaries.

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. RTV, silica tile, insulation
3. Paints, salt, rust
4. Organics and organic fibers
5. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (zinc, aluminum, stainless and carbon steel alloys) are common to SRB/BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, silica tile, and insulation originate from Orbiter thermal protection system (TPS).

3. Paint is of flight hardware/facility/GSE origin; salt is a naturally-occurring landing site product; rust is an SRB BSM exhaust residue.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity. Organic fibers appear to originate from the sample cloth used for sampling.

5. Earth compounds (alpha-quartz, calcite, calcium-rich and silica-magnesium) originate from the landing site.

Orbiter Crew Hatch Window

Results of the Orbiter crew hatch window sample indicated the presence of the following materials:

1. Trace metallics
2. RTV, silica tile, insulation
3. Paint, rust, salt
4. Earth compounds
5. Organics and organic fibers

Debris analysis provides the following correlations:

1. Trace metallics (zinc, aluminum, stainless, and carbon steel alloys) are common to SRB BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, silica tile, and insulation originate from Orbiter thermal protection system (TPS).

3. Paint is of flight hardware/facility/GSE origin; rust is an SRB BSM exhaust residue; salt is a naturally-occurring landing site product.

4. Earth compounds (alpha-quartz, calcite, calcium-rich, and silica-magnesium rich materials) originate from the

   landing site.

5. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. Organic fibers appear to originate from the cloth used for sampling.

Conclusions

The STS-46 mission sustained Orbiter tile damage to a greater than average degree. The chemical analysis results from post flight samples did not point to a single source of damaging debris.

Orbiter window samples provided evidence of SRB BSM exhaust, Orbiter TPS, Orbiter window polishing compound, landing site products, organics, and paint. Window polish residue and glass fibers, which are materials that have been previously detected, were not observed in this mission's chemical sampling results (reference Figure 19).

The Orbiter crew hatch window sample results revealed SRB BSM exhaust residue, Orbiter TPS materials, landing site products, organics, and paint. This data is consistent with that observed in previous sampling (STS-33R, reference Figure 19).

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
46	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Alpha-Quartz, Salt (L/S) Organics Paint				Crew Hatch Window - Metallics - BSM Residue (SRB) - Alpha-Quartz, Salt (Landing Site) - RTV, Tile (ORB TPS) - Paint - Organics
50	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Window Polish Residue (ORB) Mica, Calcium, Salt (Landing Site) Organics Paint		Silica-Rich Tile (ORB TPS)		Orbiter Vertical Stabilizer - Tile Coating (ORB TPS) - Structural Coating Glass "E-Glass"
49	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Calcium, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Rust - BSM Residue (SRB) Muscovite, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Rust - BSM Residue (SRB) Calcium Mat'l,Salt (Landing Site Soil) Organics Paint		
45	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		Iron - Rich Mat'l Paint		
42	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint		Metallics - BSM Residue (SRB) Tile, Tile Coating (ORB) Salt (Landing Site) Paint	Organics	RH Fuselage - Tile Coating (ORB)
44	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Organics Silica-Magnesium Mat'l	

Figure 19. Orbiter Post-Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
48	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Metallics Silica - Rich Mat'l (Landing Site) Orb Umbilical C/O Mat'l (ORB) Paints	
43	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Salt (Landing Site) Organics Paint		Runway - FRSI Coating (ORB)
40	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint	RTV,Tile (ORB TPS)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Organics (ORB Umb C/O) Paint	
39		Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint Hypalon Paint (SRB)	Tile (ORB TPS) Insulation Glass (ORB TPS)		
37	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics Paint	RTV, Tile ((ORB TPS) Insulation Glass (ORB TPS) Metallics - BSM Residue (SRB) Calcite, Salt (Landing Site) Organics		
35	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Organics	RTV, Tile (ORB TPS) Metallic - Rust, Aluminum Welding Slag (Facility)		
38		RTV, Tile (ORB TPS) Hypalon Paint (SRB) Ensolite Foam (RCC Prot. Cover)	Tile (ORB TPS)		
41	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Tile (ORB TPS) Salt (Landing Site)	Tile (ORB TPS)	Calcite (Landing Site) Fluorocarbon (Viton-ORB Umb) Foam (ORB C/O)	Fwd FRSI - Silicon Mat'l (ORB TPS)

Figure 19 Orbiter Post [illegible]

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
31R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Foam Insulation (ET/SRB) Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Paint		
36	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint	Rust - BSM Residue (SRB) Tile (ORB TPS) Paint Organics	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Microballoon (ET/SRB)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Microballoon (ET/SRB) Calcite (Landing Site) Foam, Organics (ORB Umb C/O)	
32R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) Tile (ORB TPS) Carbon Fibers Titanium	Metallics - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Quartz, Calcite (Landing Site) Organics	
33R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Micaceous Mat'l, Salt (Landing Site) Window Polish Residue (ORB) Paint	Metallics - BSM Residue (SRB) Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Spar, Salt (Landing Site) Organics	RTV, Tile (ORB TPS)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Paint Organics	Crew Hatch Window - Rust - BSM Residue (SRB) - Alpha Quartz (TPS/Landing Site) - Paint - Organics
34	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Alpha-Quartz, Silicates, Salt (L/S) Window Polish Residue (ORB)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Paint	RTV, Tile (ORB TPS) Stainless Steel Washer	RTV (ORB) Foam (ORB) Viton Rubber (ORB) Metallics - BSM Residue (SRB) Phenolic Microballoon (ET/SRB) Silicates, Calcium (Landing Site) Paint	
28R	Silicone (ORB FRCS Cover Adhesive)	Silicates (Landing Site) Paint Charred Silicone Brass Chip	RTV, Tile (ORB TPS) Clay, Sand, Quartz (Landing Site) Metallics - BSM Residue (SRB)	Sand, Silicates (Landing Site) Foam (ORB) RTV (ORB TPS) Koropon, Kapton (ORB) Metallics - BSM Residue (SRB)	OMS Pod - PVC Laminate (ORB TPS 'Shim')
30R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Clay, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Gap Filler (ORB TPS) Clay, Feldspar (Landing Site)		Upper Tile - Tile,Gap Filler (ORB TPS)

Figure 19. Orbiter Post-Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
29R	RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Ablator, Hypalon Paint (SRB)		Tile (ORB TPS) Insulation Glass (ORB TPS) Paint Muscovite - Metallics (Landing Site)	Tile (ORB TPS) Umbilical Foam (ORB) Paint Ablator, Hypalon Paint (SRB) Metallics - BSM Residue (SRB)	Upper Tile - Tile (ORB TPS)
27R	RTV, Tile (ORB TPS)	Hypalon Paint (SRB)	RTV, Tile (ORB TPS) Ablator, Hypalon Paint (SRB)		OMS Pod - Iron Fiber - PDL Foam, FRL Paint (ET) - Ablator, Hypalon Paint (SRB)
26R			RTV, Tile (ORB TPS) Paint Rust		

Sample locations vary per mission and not all locations are sampled for every mission.
( ) - Identifies the most probable source for the materall.
Metallics - Includes mostly Aluminum and Carbon Steel alloys

Figure 19. Orbiter Post-Landing Microchemical Sample Results

9.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 3 Post Launch Anomalies were observed on the STS-46 mission assessment.

9.1 LAUNCH PAD/FACILITY

1. The hydrogen burn ignitor at the southeast corner of the LH2 TSM malfunctioned. The ignitor burned 1.3 seconds (nominal burn time is 8-12 seconds) and was completely expended prior to SSME ignition.

9.2 EXTERNAL TANK

1. PR ET-48-TS-0027 documented two cracks (8 and 4 inches, respectively, by 1/4-inch wide) in the forward surface BX-250 TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. Both cracks exhibited no offset and were not filled with ice or frost. Due to the proximity of the cracks, the possibility existed for loss of TPS material in flight. Based on a debris (loss of material) and aerothermal analysis, the condition was accepted for flight. The cracks occurred in an area where the stress relief cut had been eliminated by design at the factory. ET project had determined that re-instating the stress relief crack would not be cost effective. CR S041254C added documentation to the NSTS-08303 Ice/Debris Inspection Criteria to accept for flight the presence of one crack without offset. More than one crack, or cracks with offset, would require an engineering evaluation prior to launch.

9.3 SOLID ROCKET BOOSTERS

1. A stud hang-up occurred on HDP #7. The stud remained fully extended as the aft skirt ascended. The stud pulled off three pieces of the EPON shim before dropping into the holddown post.

9.4 ORBITER

1. No items.

Appendix A. JSC Photographic Analysis Summary

September 4, 1992

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-46 Final Report, and was completed September 4, 1992. Publication numbers are LESC-30420 and JSC-25994-46. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

2.0 Summary of Significant Events Analysis

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Umbilical Disconnect Debris

(Cameras E-005, E-006, E-017, E-025, E-026, E-030, E-031, E-034, E-057, E-079, OTV109, OTV149, OTV163, OTV170)

Normal ice debris and vapors were noted falling from both the LH2 and LO2 umbilical disconnect areas at SSME ignition through liftoff. On camera OTV109, several small pieces of ice were noted striking the lower lip of the LH2 umbilical well area after SSME ignition. No vehicle damage was apparent.

2.1.1.2 TSM Debris

(Cameras E-003, OTV149, OTV163)

Normal ice debris and vapors were noted falling from both the LH2 and LO2 umbilical TSM disconnect areas at liftoff. On camera OTV163, a small piece of dark debris first seen near the LH2 TSM disconnect traveled up along the vehicle and out of the field of view at SSME ignition. On camera E-003, a rectangular piece of debris (shiny on one side) was seen moving from left to right in the field of view passing in front of the hydrogen TSM after SSME ignition. This debris did not appear to strike the vehicle.

2.1.1.3 Debris near Right Elevon

Two small dark pieces of debris were seen falling along the right elevon prior to liftoff. The debris did not appear to strike the vehicle.

2.1.1.4 Debris near LSRB

(Camera E-036)

A triangular piece of dark debris was seen falling toward the base of LSRB from left to right across the field of view after SSME ignition. The debris did not appear to strike the vehicle.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris *(Task #7)*

(Cameras E-007, E-008, E-010, E-011, E-012, E-014, E-030, E-035)

As on previous missions, several pieces of debris were noted originating from the SRB flame ducts near the holddown posts during and after SRB ignition. None of the debris was noted as fast moving. None of the debris was observed to strike the vehicle.

2.1.2.2 Debris near Holddown Posts

(Cameras E-007, E-011)

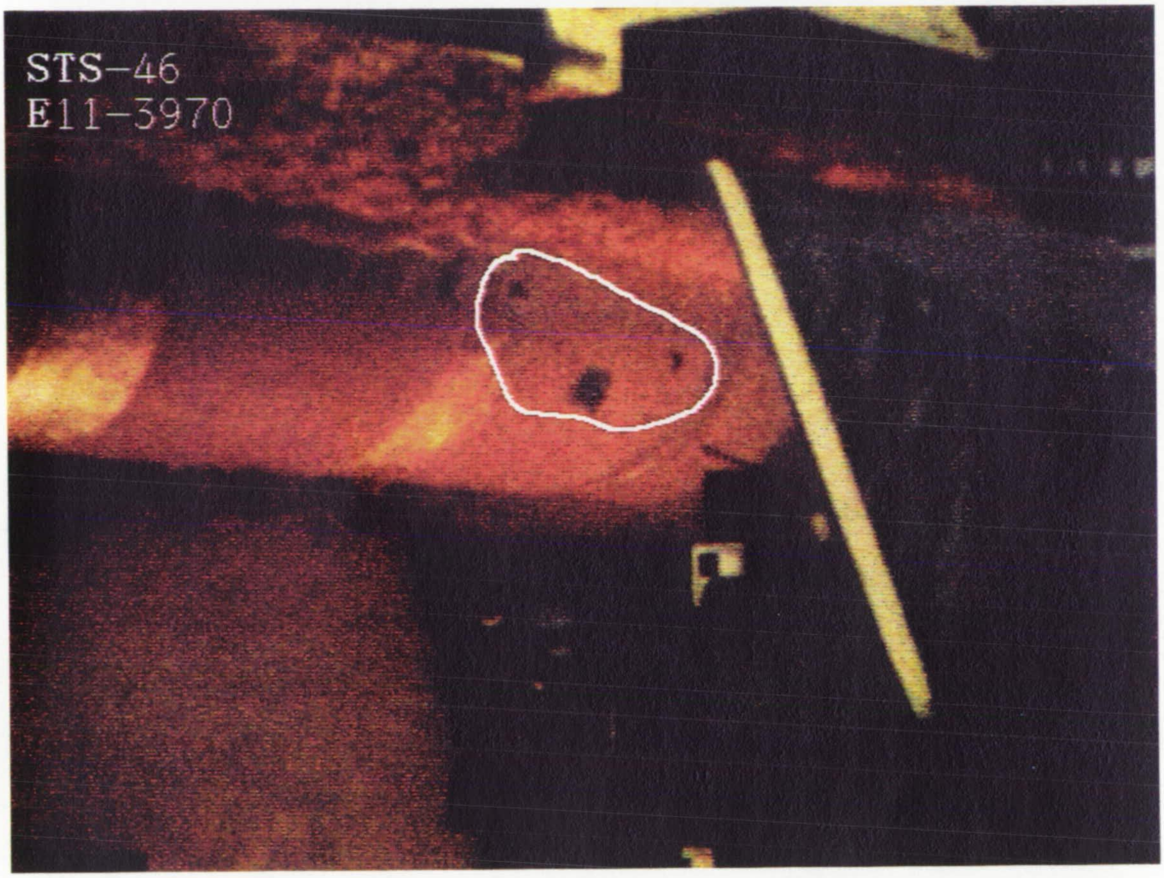


Figure 2.1.2.2 Debris near LSRB Holddown Post M-7 at Liftoff

Three pieces of dark debris (probably epon shim material) were noted falling from the LSRB holddown post M-7 foot at the time of the bolt hang up at liftoff (shown above).

A small piece of dark debris fell aft in the view of the RSRB M-4 holddown post (camera E-007) at liftoff. The debris did not appear to be from the DCS. A different piece of dark debris appeared from behind the shoe on HDP M-4 and fell into the flame duct after liftoff. None of this debris appeared to strike the vehicle. No follow up analysis of the debris seen near the holddown post has been requested.

2.1.2.3 Debris between LSRB and Left Wing
(Camera E-026, E-040)

A medium sized piece of dark debris was seen traveling from left to right between the LSRB and the left wing at liftoff on camera E-026. The same piece of dark debris appeared triangular in shape and was seen to fall between the LSRB and the underside of the left wing tip on the camera E-040 film. The debris did not appear to strike the vehicle.

2.1.2.4 Debris near LH2 TSM Disconnect
(Camera OTV149)

A medium-sized piece of dark rectangular debris was noted traveling upward from near the LH2 TSM disconnect area just after liftoff. This debris did not appear to strike the vehicle.

2.1.2.5 Debris between Orbiter Fuselage and Left Inboard Elevon
(Camera E-031)

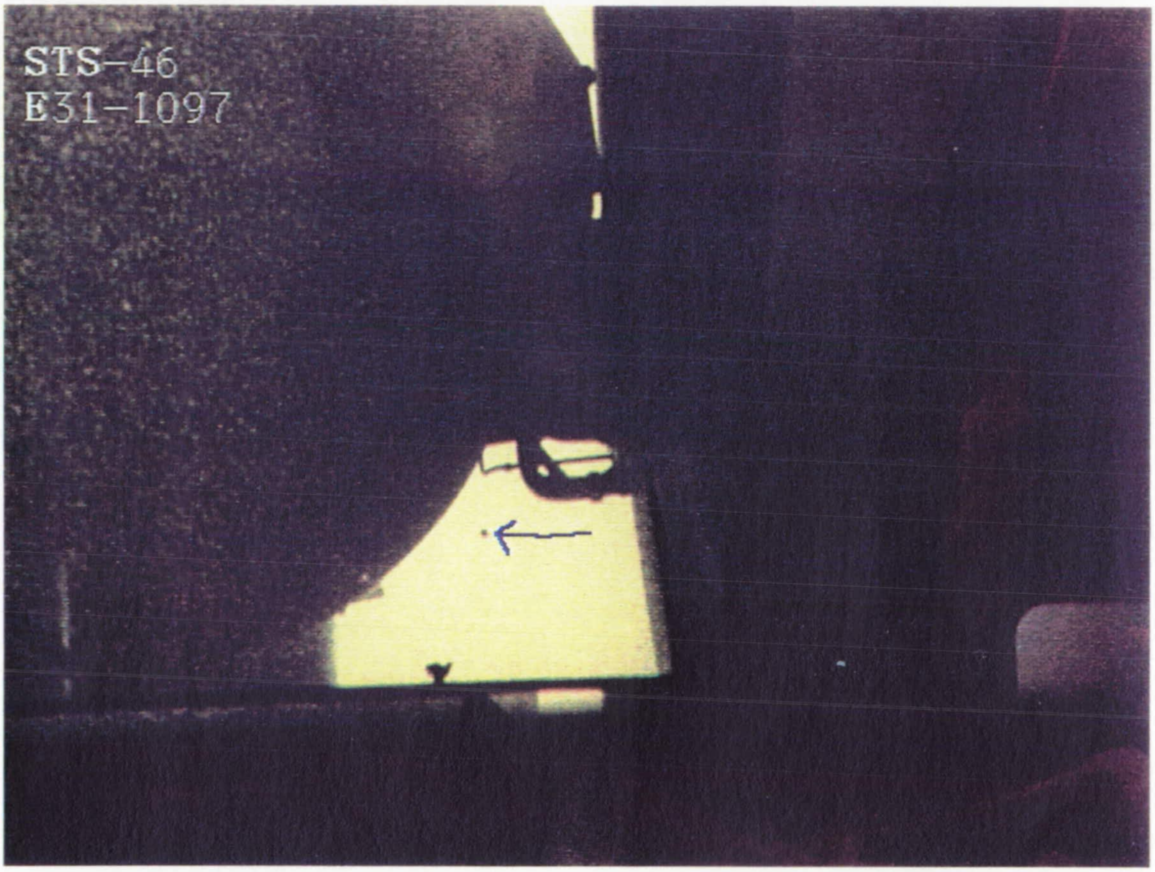


Figure 2.1.2.5 Debris between Orbiter Fuselage and Left Inboard Elevon

A single piece of dark debris, first seen aft of the ET aft dome and between the SRBs, traveled between the Orbiter fuselage and the left inboard elevon at liftoff. The debris did not appear to strike the vehicle.

2.1.3 Debris after Liftoff

Multiple pieces of debris were seen falling aft of the SLV from liftoff through ascent on the launch tracking views. Most of the debris sightings were probably RCS paper or ice from the ET/Orbiter umbilicals. None of the below-mentioned debris seen after liftoff appeared to strike the vehicle. Debris falling aft of the SLV after liftoff has been seen on films and videos from previous missions. Most of this type of debris has been attributed to ice or RCS paper. No further analysis has been requested.

2.1.3.1 SLV Debris at Tower Clear through Roll Maneuver *(Cameras E-057)*

Several pieces of white debris were seen falling from the ET/Orbiter umbilical area into SSME exhaust plume just after tower clear A small piece of white debris was seen moving past the vertical stabilizer and fall aft at T+7.7 seconds MET.

2.1.3.2 Debris near LSRB at 31-32 Seconds MET *(Task #12)* *(Camera KTV4B)*

A single piece of light colored debris noted to the left of the LSRB was seen falling aft at approximately 31 seconds MET. This debris may have originated from the top of the SLV. Another single piece of light colored debris first noted behind the LSRB was seen falling aft along the SRB plume at approximately 32 seconds MET.

2.1.3.3 Debris near Right Wing at 39 Seconds MET *(Camera E-222)*

A light colored piece of debris was seen coming from near the right wing and moved aft at approximately 39 seconds MET.

2.0 Summary of Significant Events Analysis

2.2 MLP Events

2.2.1 Premature Firing of Hydrogen Igniter
(Camera E-003, E-020))

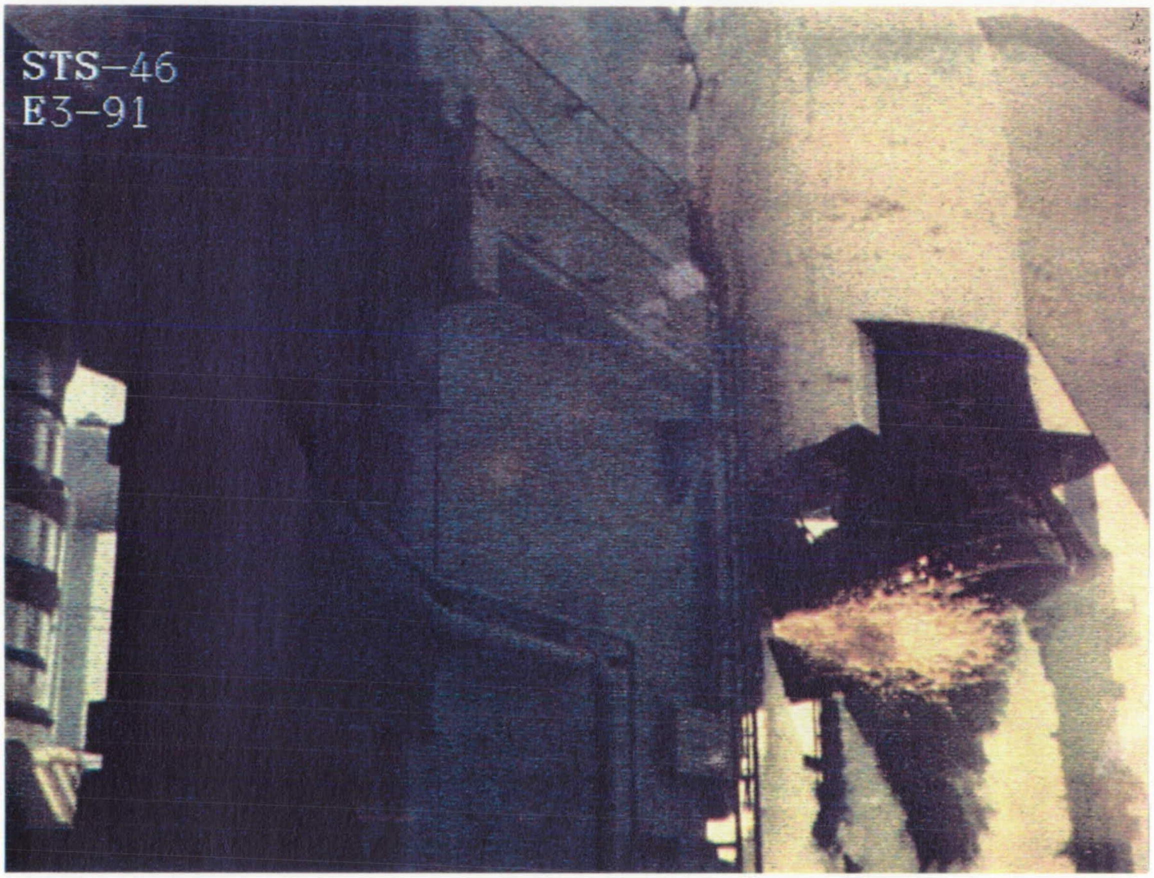


Figure 2.2.1 Premature Firing of Hydrogen Igniter

The southwest hydrogen igniter on the LH2 TSM fired too fast and ended prematurely (before SSME startup). The southwest hydrogen igniter stopped firing at T-8.634 seconds as read from the Camera E-3 film. No follow-up analysis is expected.

2.2.2 Orange Vapor
(Cameras OTV163, OTV170, OTV171)

Orange vapor (possibly free-burning hydrogen) was noted beneath the body flap just prior to SSME ignition. This vapor appeared to be similar to that noted on previous missions. No further analysis has been requested.

2.2.3 Apparent Excessive Motion of SSME #2 at Engine Start Up
(Task #9)
(Camera E-077, OTV171)

The SSME #2 engine bell appeared to move more than SSME #1 or SSME #3 during engine startup when viewed on the Camera E-077 film (recorded at approximately 96 frames per second) and the OTV171 video. A study was requested to determine if there was above normal vibration in the STS-46 SSME #2 at engine startup. The apparent motion was compared to the STS-37 Camera E-077 film to determine if the motion is typical when viewed from the same perspective. STS-37 was also a morning launch from pad 39B on a 28.5 degree inclination. Data points for each mission camera on a series of frames on the same fixed point on the Mobile Launch Platform (MLP) and the same points along a major and minor axis on the SSME #2 bell were obtained. Calculations were made to determine the lengths of the axis for both the x and y directions. Analysis of measurements made from the two mission films indicated that there was no significant difference in the movement of SSME #2 on the two missions.

Video cameras OTV171 from STS-46 and OTV071 from STS-40 (almost identical views) were also used in the analysis. Images were captured on the real time disk from STS-46 and STS-40 and measurements were made on the engine bell motion. Again, no substantial difference in the SSME #2 motion was found. The largest relative change was in the major length for STS-46 which was 8.5 inches as compared to 5 inches for STS-40 The relative change in the minor length was the same value - six inches. All other comparisons between missions produced identical values. The results of these measurements are presented in Section 6.0, Appendix C, Task #9. No follow up analysis is expected.

2.2.4 Flexing of Base Heat Shield
(Cameras E-076)

A slight flexing was seen in the base heat shield after SSME ignition. Flexing of the base heat shield was first reported on STS-49 and was also found on several other previous missions views of the base heat shield when the films were rescreened. No follow up action has been requested.

2.2.5 Orange Discoloration in SSME Exhaust Plume
(Cameras E-002, E-062, E-063, E-076, E-077, E-222)

Orange discolorations were noted in the SSME #1, #2 and #3 plumes prior to and at liftoff. Nine discolorations in the SSME #2 mach diamond were timed on the camera E-222 film between T-1.835 seconds to T+0.532 seconds. The interval between the nine discolorations averaged 0.296 seconds with no noticeable frequency pattern. Two discolorations were seen in the SSME #1 mach diamond at T-0.148 seconds and T-0.742 seconds on the E-222 film. One discoloration was seen in the SSME #3 mach diamond at T-2.007 seconds.

2.2.6 Flashes in SSME Plumes after SSME Start Up
(Cameras E-001, E-002, E-003)

On camera E-001, two orange colored flashes were noted in the SSME #2 exhaust plume prior to liftoff. On cameras E-002, E-003, two orange colored flashes were noted in the SSME #1 plume while the vehicle was still on the launch pad. Events similar to these seen in the past were often found to be caused by RCS paper and other debris. Flashes in the SSME exhaust plumes at engine ignition have been seen on previous missions. No follow up analysis is expected.

2.2.7 Base Heat Shield Erosion
(Cameras E-017, E-019 and E-020)

On camera E-020, slight base heat shield erosion was noted between the left OMS nozzle and the left RCS stinger. On camera E-017 and E-019, TPS erosion was noted on the tip of the right RCS stinger. TPS erosion on the base heat shield and RCS stingers has been seen on previous mission films. No follow up action has been requested.

2.2.8 LSRB HDP M-7 Bolt Hang-up
(Camera E-011)

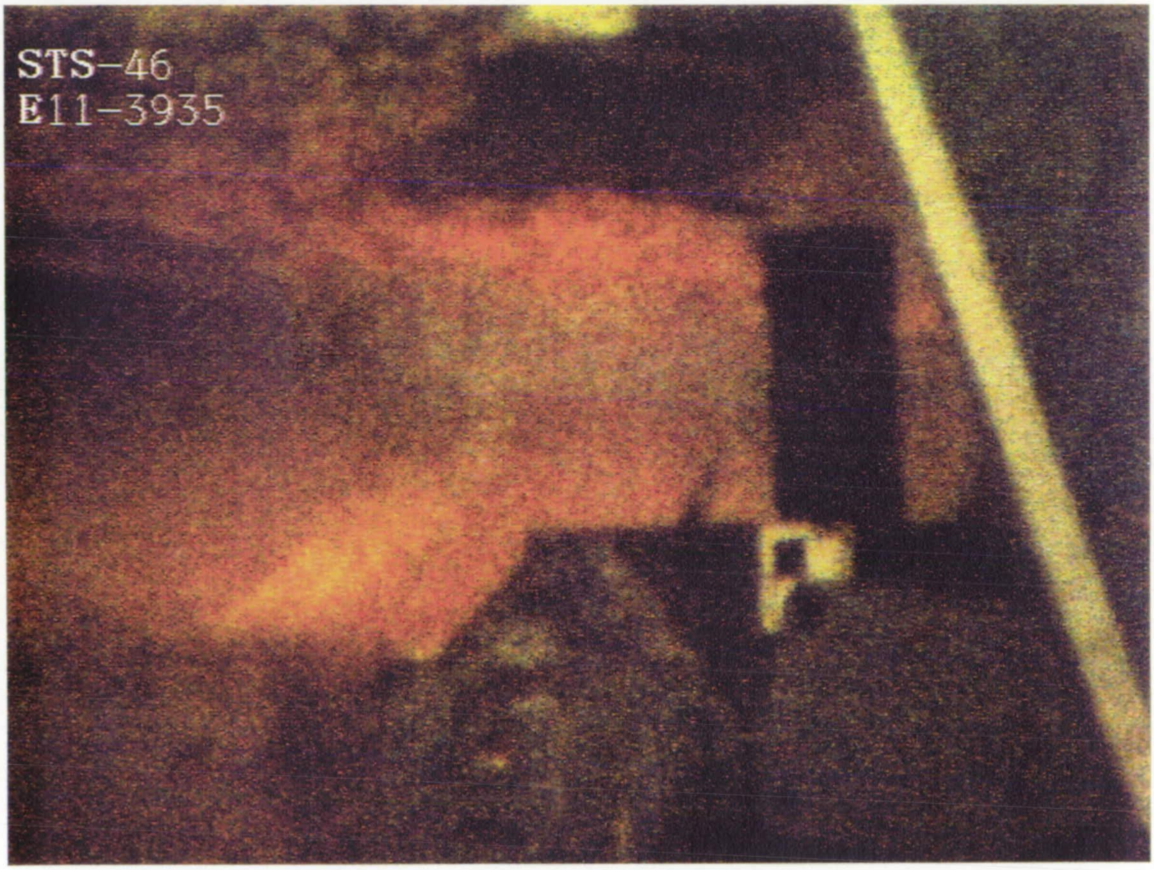


Figure 2.2.8 **Bolt Hang-up at LSRB HDP M-7 During Liftoff**
(Camera E-011)

On camera E-011 a bolt hang up on the left SRB holddown post number M-7 was noted. The bolt hung up in the SRB debris containment system (DCS) area. The visible extent of the bolt hang up was measured to be 13.11 inches on the camera E-011 film where the bolt appeared to be at maximum extension. A review of previous occurrences of bolt hang ups since reflight was conducted. Bolt hang ups have occurred on six previous missions since reflight. Five of the seven bolt hang ups were on the RSRB. No further photographic analysis is expected.

2.0 Summary of Significant Events Analysis

The missions where bolt hang ups have occurred are:

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4
STS-50	RSRB holddown post M-4
STS-46	LSRB holddown post M-7

2.3 Ascent Events

2.3.1 Flares in SSME Exhaust Plume
(Cameras E-052, E-213, E-220, E-222, E-223, KTV21A, ET207, ET212)

Multiple flares were seen in the SSME exhaust plume after liftoff on these long range tracking views. The flares were timed at 6.163, 14.890, 22.586, 27.872, 30.160, 34.322, and 36.992 seconds MET on the cameras with digital timing. Flares during this time period have been seen on several earlier missions. No further analysis is expected.

On cameras ET207, ET212, two flares were noted in the SSME plume: the first was at approximately 33 seconds MET and the second was at approximately 43 seconds MET.

2.3.2 Body Flap Motion *(Task #4)*
(Cameras E-207,E-212, E-220, OTV163))

Slight body flap motion was seen after the roll maneuver on these long range tracking camera views. Slight body flap motion was also seen prior to liftoff at T-2.2 seconds on Camera OTV163. Body flap motion has been seen on previous mission films and the magnitude of the body flap motion seen on the STS-46 views is not sufficient to warrant further analysis. No follow up action is expected.

2.3.3 Orange Puffs in SSME Exhaust Plume

(Camera E-220)

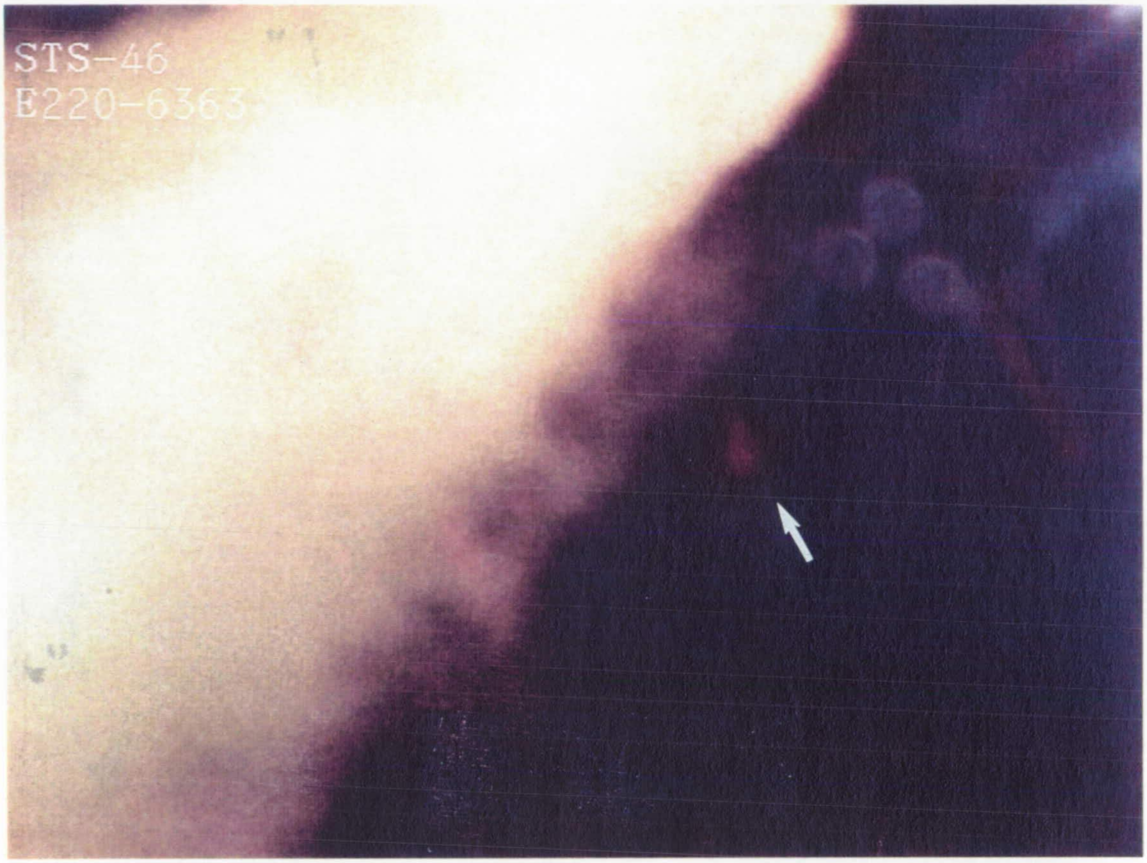


Figure 2.3.3 Orange Puffs in SSME Exhaust Plume

An orange puff was seen in the SSME exhaust plume at approximately 27.7 seconds MET and again at approximately 52.6 seconds MET (shown above) on the camera E-220 film. The cause of these puffs was not determined. No follow up action has been requested.

2.3.4 Orange Streak

(Camera ET208)

A bright orange linear streak was seen moving forward from the top of the left SRB exhaust plume to the SRB aft skirt area at approximately 87 seconds MET. This phenomenon was only seen in two frames and may have been caused by an atmospheric optical effect or a video distortion. No follow up action is expected.

2.3.5 Recirculation *(Task #1)*

(Cameras ET204, ET208, KTV13, E-204, E-208, E-212, E-218 and E-220)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all the previous missions. For STS-46, the start of recirculation was observed at about 96 seconds MET and the end was noted at approximately 112 seconds MET on Camera KTV13. See Appendix D for a summary of recirculation start and stop times for all missions since reflight.

Cameras on which recirculation was observed for STS-46

CAMERA	START (seconds MET)	STOP (seconds MET)
ET204	-	-
*ET208	96	112
KTV13	96	111
E-204	-	-
E-208	97	107
E-212	96	106
E-218	-	-
E-220	-	-

* **BEST VIEW OF RECIRCULATION**

2.3.6 Orange Pulse in SRB Plume before SRB Separation

(Camera ET208)

An orange pulse was seen in the SRB plume at approximately 113 seconds MET. This pulse was seen before the beginning of normal plume brightening. No follow up action is expected.

2.4 On Orbit

2.4.1 Tethered Satellite System (TSS) Support

The STS-46 tethered satellite system (TSS) was recorded real time during both the satellite deploy and docking. No follow up video analysis support has been requested.

2.4.2 Onboard Hasselblad ET Analysis - DT0-312 *(Task #6)*

Frame 46-71-03

Frame 46-71-04

Figure 2.4.2 Photographs of External Tank After ET Separation

The handheld hasselblad ET separation photographs shown above were taken on STS-46 by Jeff Hoffman. The photographs were taken through the overhead window at 14:17:41 UTC or approximately 21 minutes after liftoff (12 minutes after ET separation). The views are of the Orbiter side of the ET and the aft dome. The external tank appeared to be in good condition with no visible divots or other anomalies. The bright spots seen on the LO2 feedline, pal ramps, forward Orbiter attach bipod, and the aft Orbiter attach brace were caused by reflected sun light.

2.5 Landing Events

2.5.1 Landing Sink Rate Analysis *(Task #3)*

2.5.1.1 Landing Sink Rate Analysis Using Film *(Camera EL009, EL012)*

Camera EL009 film was used to determine the sink rate of the main gear. The right inboard tire was used to scale the measurements. Data was gathered for 2.146 seconds prior to landing through touchdown. Three points on every other frame over a period of 200 frames were digitized. These points consisted of the top and bottom of the right tire and a point on the runway immediately beneath the wheel. This raw data was corrected for the vertical change in scale at each frame. The distance between the bottom of the wheel and the runway was computed and a linear regression was applied on this normalized vertical distance vs. time data to find the actual sink rate. This rate was determined to be 2.6 ft/sec. which is well within the current threshold limits.

Nose gear touchdown occurred approximately 15 seconds after main gear touchdown. Camera EL012 was used to determine the nose gear sink rate. The right inboard tire was used to scale the measurements. Data was gathered for the 2.083 seconds prior to nose gear touchdown. Four points on every other frame over a period of 100 frames were digitized. These points consisted of the bottom of the left nose wheel, a point on the runway surface immediately beneath the nose gear and the top and bottom of the right inboard main gear. This raw data was corrected for the vertical change in scale at each frame. The distance between the bottom of the wheel and the runway was computed and a linear regression was applied on this normalized vertical distance vs. time data to find the actual sink rate. This rate was determined to be 2.1 ft/sec. which is also well within the current threshold limits.

Graphs depicting the above data can be seen in Task #3 Appendix D.

2.5.1.2 Landing Sink Rate Analysis Using Video *(Camera KTV33)*

A single camera sink rate was calculated for the main gear of the vehicle using a single camera solution. Positional information was acquired by digitizing the landing sequence and then obtaining a screen dump of cursor positions at the points of interest. The positional information was then scaled to actual position and a linear least squares line was fitted through these points as a function of time. The main gear sink rate was calculated to be 1.3 feet per second and the nose gear sink rate was calculated to be 3.0 feet per second. A sink rate plot is located in Appendix D Task 3. No follow-up action has been requested. See Appendix D Task #3 for details.

Results from the film analysis are considered better than video because of the higher spatial resolution.

2.6 Other Normal Events

Other events seen on the STS-46 launch views that have been seen on previous shuttle flights include: frost buildup around the ET/Orbiter umbilical baggy area and ET vent louvers; smoke from hydrogen ignitor startup; normal pad debris; RCS paper debris; white debris (probably ice) from the GUCP disconnect during liftoff; twang; slight vibration from the elevons at liftoff; MLP debris in the SLV exhaust plume after liftoff; ET aft dome outgassing and charring after liftoff; vapor off SRB stiffener rings after liftoff; condensation trails from the SLV after the roll maneuver; atmospheric bow waves (expansion waves); linear optical effect and SRB exhaust plume brightening at tail off.

A water leak in a MLP J-pipe was seen prior to liftoff on cameras E-011, E-015, and E-016.

Appendix B. MSFC Photographic Analysis Summary

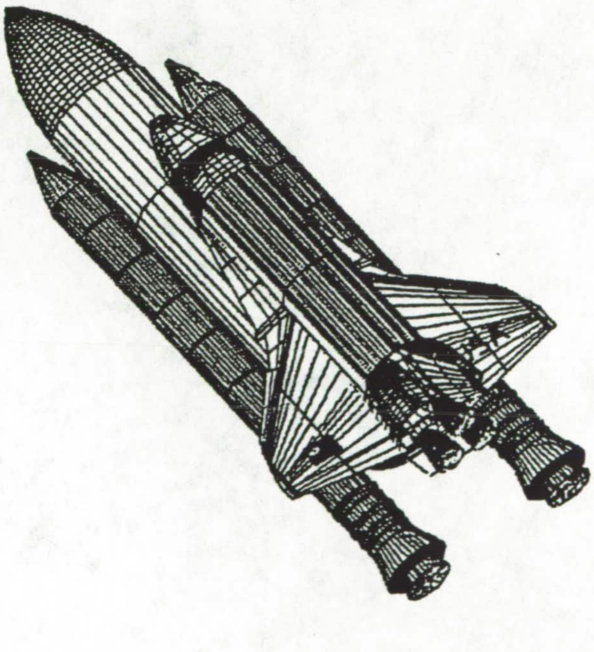
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-46



MSFC - Form 454 (Rev. October 1976)

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

Attn of: EP55 (92-75)

August 20, 1992

TO: Distribution

FROM: EP53/Tom Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-46

Enclosed is the Engineering Photographic Analysis Report for the Space Shuttle Mission STS-46. For additional copies, or for further information concerning this report, contact Tom Rieckhoff at 544-7677, or Darlene Busing, Rockwell at 971-3174.

Tom Rieckhoff

Tom Rieckhoff

Enclosure

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-46

FINAL

PREPARED BY:

J. HIXSON, D. BUSING, B. VIGER, W. LANGLOIS
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:

JIM ULM
ACTING MANAGER, LAUNCH AND FLIGHT OPERATIONS/ROCKWELL/HSV

APPROVED BY:

T. RIECKHOFF, MSFC/EP55
B. LINDLEY-ANDERSON, MSFC/EP55

STS-46 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

August 17, 1992

I. INTRODUCTION

Space Shuttle Mission STS-46, the twelfth flight of the Orbiter Atlantis, was conducted July 31, 1992 at approximately 8:56 A.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-46 included, but were not limited to the following.

a. Overall facility and Shuttle vehicle coverage for anomaly detection
b. Verification of cameras, lighting and timing systems
c. Determination of SRB PIC firing time and SRB separation time
d. Verification of Thermal Protection System (TPS) integrity
e. Correct operation of the following:
   1. Holddown post blast covers
   2. SSME ignition
   3. LH2 and LO2 17" disconnects
   4. GH2 umbilical
   5. TSM carrier plate umbilicals
   6. Free hydrogen ignitors
   7. Vehicle clearances
   8. GH2 vent line retraction and latch back
   9. Vehicle motion

There was one special test objective for this mission.

a. DTO-0312, ET photography after separation

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-three of fifty-five requested cameras as well as video from twenty-two of twenty-three requested cameras. The following table illustrates the camera data received at MSFC for STS-46.

CAMERA DATA RECEIVED FOR STS-46

	16mm	35mm	70mm	Video
MLP	22	0	0	3
FSS	7	0	0	3
Perimeter	3	4	0	5
Tracking	0	14	0	11
Onboard	2	0	1	0
Totals	34	18	1	22

A detailed individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

Photographic coverage of STS-46 ranged from good to poor. Coverage from the trackers was limited due to an atmospheric haze. Cameras E-52, E-54 and TV-041 all did not run due to a tracker malfunction.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly, but did not record water impact. Also, the astronauts carried a 70mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off; debris induced streaks in the SSME plume; ice falling from the 17" disconnect and umbilicals and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors, purge barrier material and SRB thermal curtain tape.

b. SRB Holddown Post M-7 Stud Hang-up:

Figure one is a frame of film taken from camera E-11 showing holddown post M-7 stud hang-up. The stud appears to remain fully extended until the SRB aft skirt clears the extended holddown post stud. The stud also pulled loose several pieces of EPON shim material.

c. Mach Diamond Color Change:

Figure two is a film frame taken from camera E-77 showing the change in color of the mach diamond of SSME #2. After reviewing cameras E-213 and E-220; more information was required. Therefore, cameras E-76 and E-77 were requested. After viewing these films all three SSME mach diamonds were observed to change orange in color. However, SSME #2 changed colors more frequently.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times were determined from cameras which view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	213:13:56:48.021
M-2	E-8	213:13:56:48.020
M-5	E-12	213:13:56:48.020
M-6	E-13	213:13:56:48.020

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 32.1 inches. Figure three is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-46 was determined to be 213:13:58:53.52 UTC taken from camera E-208.

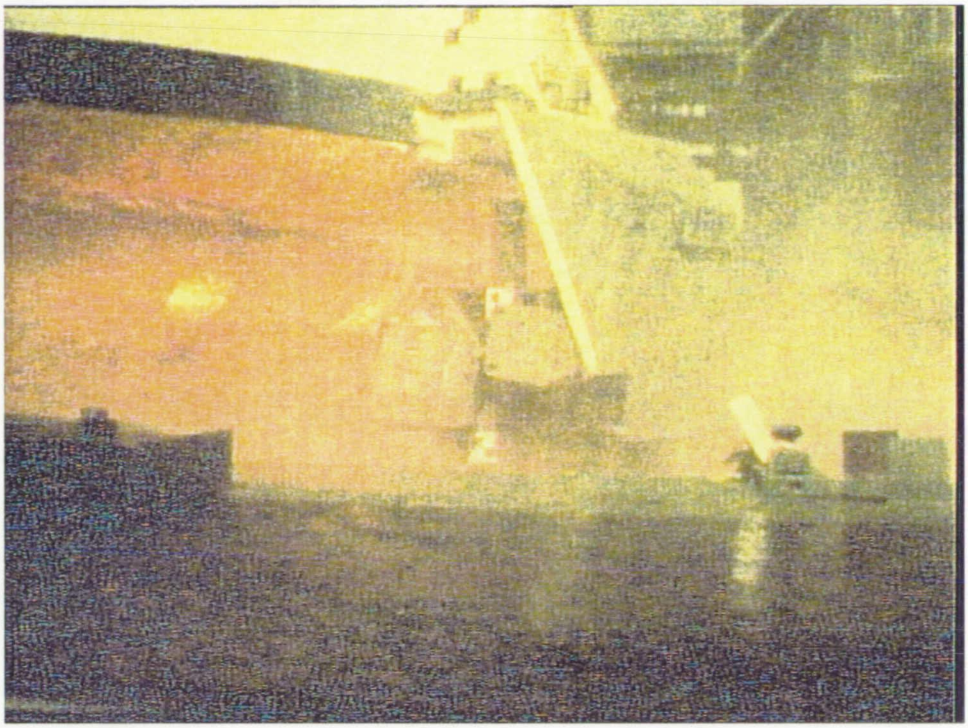


Figure 1

Holddown Post M-7 Stud Hang-up

Figure 2

Color Change in SSME Mach Diamond

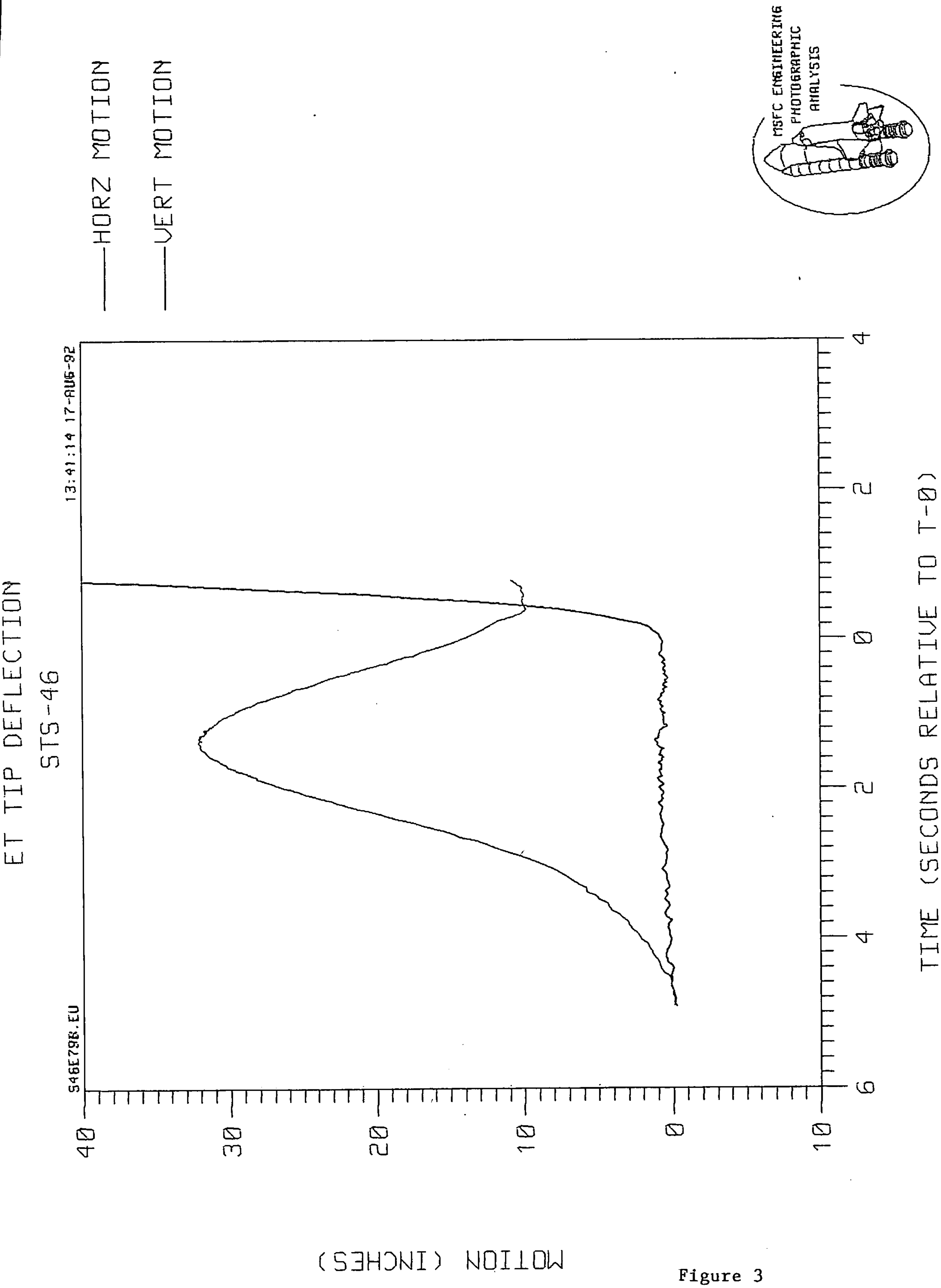

ET TIP DEFLECTION
STS-46
HORZ MOTION
VERT MOTION
MSFC ENGINEERING PHOTOGRAPHIC ANALYSIS
13:41:14 17-AUG-92
S46E798.EU
TIME (SECONDS RELATIVE TO T-0)
MOTION (INCHES)
40
30
20
10
0
10
4
2
0
2
4
6

Figure 3

Appendix C. Rockwell Photographic Analysis Summary

Space Transportation Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
Downey, California 90241

Rockwell
International

September 11, 1992

In Reply Refer to 92MA3739

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: L. G. Williams (WA)

Contract NAS9-18500, System Integration, Transmittal of the Rockwell Engineering Photographic Analysis Report for the STS-46 Mission.

The System Integration Contractor hereby submits the Engineering Photographic Analysis Summary Report in accordance with the Space Shuttle Program Launch and Landing Photographic Engineering Evaluation Document (NSTS 08244).

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39B Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-46 launch conducted on July 31, 1992, at approximately 6:57 AM (PDT) from the Kennedy Space Center (KSC) and for the landing on August 8, 1992 at KSC (6:12 AM PDT).

Rockwell received launch films from 81 cameras (59 cine, 22 video) and landing films from 24 cameras (16 cine, 8 video) to support the STS-46 photographic evaluation effort. Two films, E-52 and E-54, were not available due to camera malfunctions.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good.

Overall, the films showed STS-46 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. No vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome and recirculation and brightening of the SRB plumes were visible and normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

A disturbance in the lateral acceleration strip chart data at liftoff led Rockwell Engineers (Ascent Separation Systems) to suspect there had been a bolt hang-up on one of the SRB holddown support posts. This assumption was confirmed when film E-11 was reviewed which clearly showed the post M-7 bolt to hang-up at liftoff.

(Packing Sheet NO. DM92-18968)

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Mission Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH2 umbilical hydrogen dispersal system hardware.

STS-46 was the ninth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up. Significant events that were seen include a bolt hang-up at holddown post M-7 of the left SRB at liftoff and the southwest hydrogen burnoff ignitor on the LH2 TSM which was expended early. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-46 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. A hangup of the holddown post M-7 holddown bolt on the left SRB was seen at liftoff on camera E-11. Rockwell/Downey engineers had previously reported a disturbance in the lateral acceleration strip chart data at liftoff which led them to suspect a possible holddown post bolt hangup. Bolt hangups have occurred on previous flights since return to flight. A review of the previous bolt hangups shows the five bolt hangups occurred on the right SRB on STS-34 (Post M-2), STS-33 (Post M-3), STS-39 (Post M-1), STS-48 (Post M-4), STS-50 (Post M-4) and two on the left SRB on STS-43 (post M-7) and STS-46 (Post M-7). No further analysis is planned.

2. On Cameras E-3 and E-20, the Southwest hydrogen burnoff ignitor on the LH2 TSM was observed to stop firing prior to SSME startup. The hydrogen burnoff ignitors are designed to fire from prior to SSME startup to liftoff in order to burn off any excess hydrogen which may have collected under the SSME nozzle. However, this ignitor fired its entire load (solid propellant grain containing zirconium) prior to SSME ignition. No follow-up action is planned.

3. Three pieces of debris (probably EPON shim material) were noted falling from the SRB foot on camera E-11. This was probably caused by the M-7 bolt hang-up. No further analysis is planned.

4. Orange vapor (possibly free burning hydrogen) was seen beneath the body flap just prior to SSME ignition on camera's OTV-163, OTV-170, and OTV-171. This vapor appears to be similar to the vapor noted on previous missions. It is not an issue and no follow-up action is planned.

5. On cameras E-36 and E-40, a flat triangular piece of dark debris seen falling through the field of view from left to right near the left wing tip toward the left SRB after SSME ignition. Does not appear to contact the vehicle. No further analysis planned.

6. Flexing (fore and aft motion) was noted in the base heat shield in the centerline area between the SSME cluster during the early stage of SSME ignition (camera E-76). Base heat shield movement has occurred on previous missions and no follow-up action is planned.

7. Orange flares and flashes seen in the SSME plumes (ET-207, ET-212, E-2, E-3, E-52, E-207, E-212, E-213, E-220, E-222, E-223). These observations are seen frequently and are understood to be burning of propellant impurities including RCS paper covers. No follow-up action is planned.

8. The following events have been reported on previous missions and observed on STS-46. These are not of major concern, but are documented here for information only:
   - Ice debris falling from the ET/Orbiter Umbilical disconnect area.
   - Debris (Pad, insta-foam, water trough) in the holddown post areas and MLP.
   - Butcher paper falling from the RCS.
   - Recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation.
   - Slight TPS erosion on the base heat shield during SSME start-up.
   - Debris pieces in the SSME/SRB plumes.
   - Condensation around the SLV after the roll maneuver.
   - ET aft dome outgassing and charring.
   - Slight elevon motion at SSME ignition.
   - Twang motion.
   - Body flap motion during the maximum dynamic pressure (MAX-Q) region which appeared to have an amplitude and frequency similar to those of previous missions.
   - Linear optical distortion, possibly caused by shock waves or ambient meteorological conditions near the vehicle, during ascent.

9. Cameras E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET vent umbilical structure does not violate the acceptable margin of safety.

   A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.

10. Cameras E7-16 and E27-E28 - OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

    A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

11. The landing of STS-46 occurred on runway 33 at the KSC Shuttle landing facility. Good video and film coverage were obtained and no anomalous events were observed.

This letter is of particular interest to W. J. Gaylor (VF2) and J. M. Stearns (WE3) at JSC. The Integration Contractor contacts are R. Ramon at (310) 922-3679 or C. I. Miyashiro at (310) 922-0214.

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16. Abstract

A Debris/Ice/TPS assessment and integrated photographic analysis was conducted for Shuttle Mission STS-46. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle Mission STS-46, and the resulting effect on the Space Shuttle Program.

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